AUTOMATIC BLOCK SIGNALS

AND

SIGNAL CIRCUITS

AMERICAN PRACTICE IN THE INSTALLATION AND MAINTENANCE OF SIGNALS ELECTRICALLY CONTROLLED, AND OPERATED BY ELECTRIC OR OTHER POWER

WITH DESCRIPTIONS OF THE ACCESSORIES NOW REGARDED AS STANDARD

BY

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To My

Beloved Brother

HUGH EMMOTT SCOTT

PREFACE.

THE evolution of a mechanical art results in the simplification of its apparatus. The less the number of subsidiary devices employed, and consequently the greater the number of their independent functions, the higher the state of this art. Signaling accessories, although of rapid development, have not as yet undergone the usage test that is the prerequisite to standardization and the elimination of impracticable differentiated structures. In surveying the heterogeneous types of construction employed in the signal equipment of a representative railroad system, the difficulty of selection and representation, with respect to relative significance, becomes apparent.

In a book of this character, it is extremely difficult to intelligibly exhibit continuous circuits of any great complication, owing to the restricted space available for illustrations, insets not having been resorted to. The history of signaling is not touched upon, as it is irrelevant to the character of the present work. Railroad terms have also been omitted, as they are meaningless to the average reader.

All-electric interlocking, a natural development of the older mechanical and electro-pneumatic interlocking, is given the attention that its importance merits. Electric railway signals are described as fully as seems advisable, since they are in a transitory state of rapid progress. Electro-gas and three-position signals, representing the highest development of the art in America, have been treated not only from an electrical standpoint, but also from a structural point of view.

This book is intended for the signal and railway engineer, the electrician, and the layman; and it is modestly hoped that it will appeal to all in any way concerned with signaling.

The old argument of normal danger *vs.* normal clear is not taken up; nevertheless, data on both these systems of indication is given throughout the book, the reader being left to his own conclusions as to their relative merits.

The writer wishes to acknowledge several courtesies received from the signal companies whose products have of necessity been described, and also to Messrs. H. S. Balliet, J. C. Jones, B. H. Mann, M. E. Smith, W. W. Slater, and A. J. Wilson.

Criticisms are respectfully invited.

R. S.

Wilkesbarre, Pa.

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AUTOMATIC BLOCK SIGNALS.

CHAPTER I.

PRELIMINARY CONSIDERATIONS.

A block is a length of railroad track of defined limits, the use of which by trains is under the control of one or more block signals.

A **block signal** is a fixed arrangement controlling the use of a block.

An **automatic block signal** is one automatically operated by electrical or other energy, this agency being controlled by the passage of trains along the track, or by conditions which interfere with such movement.

A **block system** is a series of consecutive blocks controlled by block signals.

A **home signal** shows the condition of the block directly in front of a moving train; and a **distant signal** the condition of the second block in front, or the block in the rear of the home block.

An **advance signal** shows the condition of a block in conjunction with the home signal of that block. It is placed in advance of the home signal.

In Fig. 1 two signals, having home and distant semaphores, blades, or boards, are shown, with the track protected by each; train movement being in the direction of the arrows. The entire home block, consisting of two sections of the first signal, is represented; and one section of the home block of signal 2, which latter is also the first section of the distant block of signal 1.

A block is usually made about one mile long, although a large amount of traffic, the presence of an interlocking plant, numerous switches, or the necessity of slow-speed movements may

require less length. On the other hand, blocks in a sparsely settled district, with thin traffic, can be of greater length. These blocks are protected in automatic visual systems by a disk, semaphore, or revolving member by day, and by colored lights at night; these giving warning of the presence of a train, broken rail, open switch, car outside the clearance point at sidings, an open drawbridge, hand car on the track, or defect in the apparatus.

There are several ways of indicating a danger, caution, or clear condition, among which are: (1) color systems; (2) position systems; (3) motion systems. A type of the first is a colored disk moving before a white surface, either the former or the latter being visible; of the second, a blade or semaphore which is held at various angles to the track; when horizontal, "danger" or

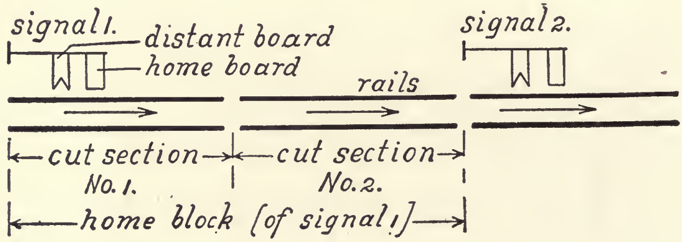


FIG. 1

"stop" being indicated, and when nearly vertical, "proceed" or "clear." Semaphores may be colored also, and thus become of the first type. The third or motion signal utilizes a revolving member, whose motion indicates that an approaching train may continue to move, and when stationary that the engine must come to a stop. At night a light is flashed intermittently by this member. Such systems, and also illuminated semaphores, have been abandoned, and therefore will not be described.

Usually, signals are numbered in such manner that these numerals will indicate the number of miles and tenths of a mile that the signal is distant from the chosen terminal. Thus on the Lehigh Valley, signal No. 1773 is 177.3 miles from New York City. On this road, odd numbers designate west bound signals and the even numbers the east bound signals. Thus it is evident that 1773 is the west bound signal 177.3 miles from New York

City (the nearest odd number to the actual tenth of a mile being chosen).

Fig. 2 shows four separate main tracks intersecting at right

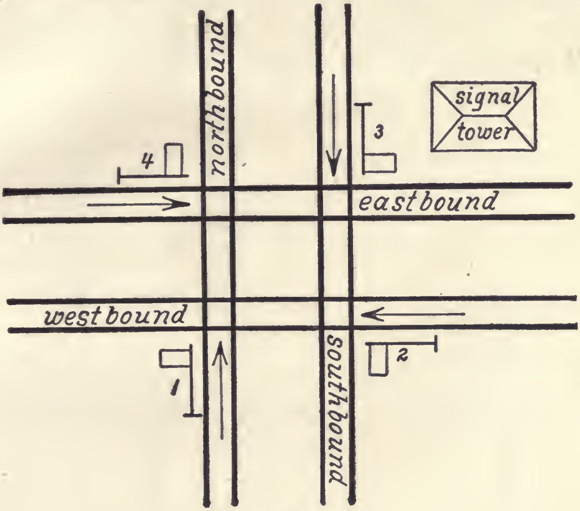


Fig. 2

angles, with their respective signals. If these are automatic, track relays, properly interconnected, can be readily arranged to give the protection desired. If they are semiautomatic, electric interlocking will be introduced to prevent conflicting of routes. Thus, when signal 3 is at clear, to allow a south bound train to pass, 1, 2, and 4 must be locked in the normal or stop position when electric locking or interlocking is used, and prevented from moving to clear if the ordinary automatic system is employed.

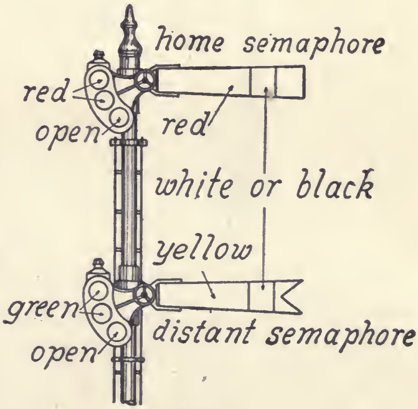


Fig. 3

A standard sixty-degree home and distant semaphore arrangement is shown in Fig. 3. Until either blade has reached a po-

sition approximating thirty degrees from the vertical it will indicate the same as though at the full horizontal position. This is effected by using several spectacles, each held in place by independent bezel rings, or by so-called continuous light spectacles. Semaphores vary in length from four to five feet, about four and one-half being regarded as standard.

Fig. 4

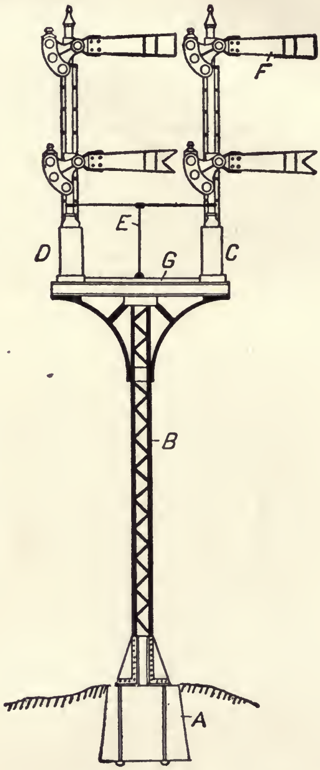


Fig. 5

A self-contained standard home and distant, three-spectacle, semaphore signal (electro-gas or motor), is shown in Fig. 4, the motor, mechanism and battery housings being at the base. This represents the highest development in external design that such signals have reached, unless exception be made of the top post arrangement.

A three-spectacle, automatic, double-route, home and distant semaphore signal is illustrated in Fig. 5. The post, *B*, consists

of two lengths of channel iron strengthened by a lattice structure, the base being bolted to, or incorporated with, a foundation of concrete, *A*. The top consists of a platform, *G*, and railing, *E*, semaphores, *F*, being pivoted to short posts and operated by motors and accessories housed in the waterproof base boxes, *C–D*. This arrangement represents the latest order of construction for the protection of two tracks having trains running in the same direction.

In Fig. 6 *A* is a short mast distant semaphore signal with an automatic mechanism housing at the base; *B* is a high home signal; *C* a short mast two-arm or double-route, *D* a high mast two-route, and *E* a three-arm or triple-route arrangement. The

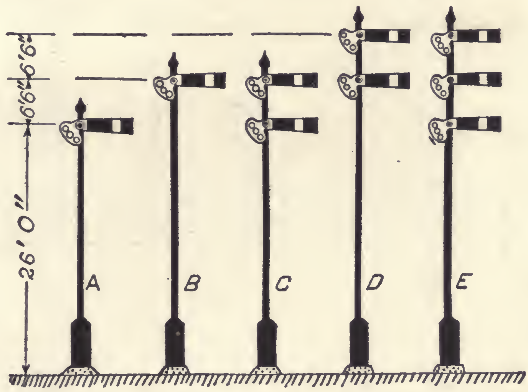


FIG. 6

standard heights of each are also given, and although this latter may vary somewhat, it represents the usual practice.

Bridge signals, which are of more substantial design than mast signals, are shown in Fig. 7. The letters designate types similar to those in the preceding figure. The tracks pass beneath the bridge at *G*. Most lines having four main tracks or over use this disposition of semaphores.

Fig. 8 shows two forms of motor-operated high signals, *A* being a single arm, and *B* a two-route arrangement. The circuit breakers, *H*, are operated by the rods, *G*, connected to the semaphore castings. The cast iron box, *A*, contains the motor and gearing constituting the signal movement (see Fig. 119), and part of the sheave, *B*, which carries the chains, *C*, projecting

from below. The blades are connected to the counterweighted levers, *E*, resilient members, *D*, being introduced to prevent injury to the parts when they fall, or should the motor wind up too high. Reversal of the motor on *B* is effected by a ground selector, described in Chapter XIV.

The electric-motor semaphore signal has several advantages, among which may be mentioned: (1) localization, it being self-contained, and therefore independent of all other signals; (2) comparatively large reserve power; (3) an isolated plant is not required for its operation; (4) economy of installation and operation; (5) working and control functions are unified; (6) external simplicity of design.

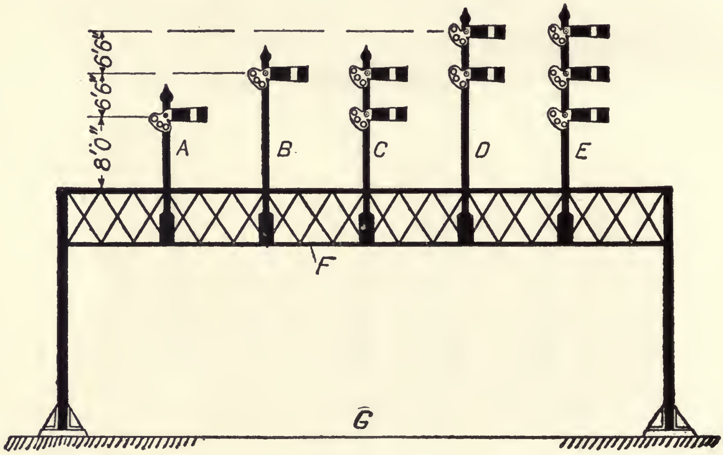


Fig. 7

The motor and control mechanism is somewhat complicated, and numerous factors of failure have been necessarily introduced. A clumsy structure is used to transform the high-speed rotary armature movement into a slow, direct reciprocating motion, while the motor itself is not a perfectly reliable device under the restrictions that must be imposed upon it. Frost may accumulate upon the commutator, the lubricant may gum, or the mica cause an open circuit, thus resulting in inoperation. The clutch or slot magnet armatures may also freeze in the clear position, as they are not acted upon by a powerful force.

The generic purpose of the electric circuits applied to devices

whose electrical operation establishes the right of train movement, is to prevent conducting continuity when a conflicting or non-clear condition exists. Thus imagine a home-signal receptive device whose energization cannot occur until twenty-four independent contacts have been closed, each having a function

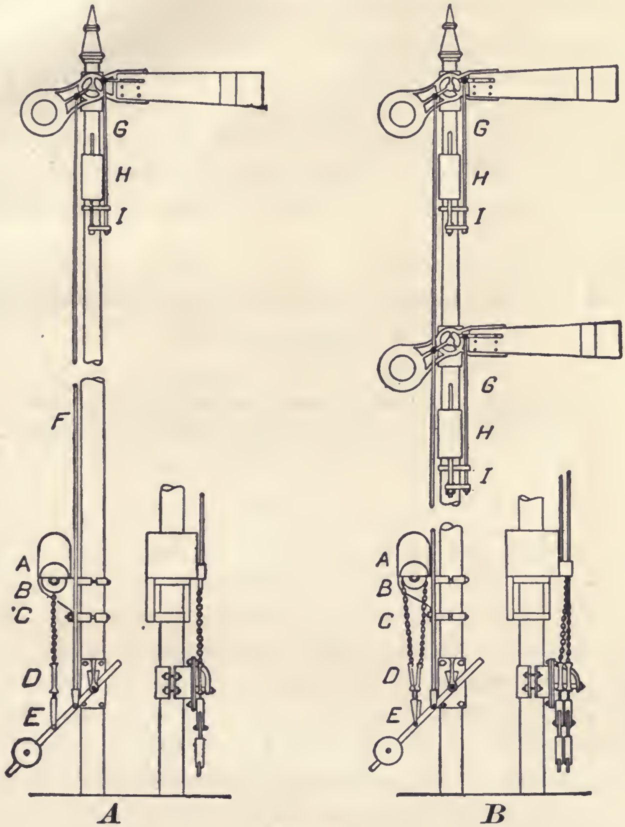


Fig. 8

which determines the right to proceed; then the opening of any one or more of these prevents the flow of current which is obviously the concomitant of a clear condition. It is the comprehension of this principle which will render evident the application of signal circuits and their close approach to being an ideal selective intermediary.

Commercial signal circuits may be divided into two parts, which are more or less generic according to the system employed. These are respectively control circuits and working circuits.

Usually a control circuit has a relatively low impressed voltage, and the circuit wires are not of great length. The most common type of control circuit is that constituting what is ordinarily termed the "track circuit," which includes the rails of the section to which it is applied, with the requisite track battery, relay, and interconnecting wires. The primary purpose of the control circuit is to close and open another circuit, the latter delivering considerable energy and actuating the devices included in the direct operation of the signal banner or semaphore.

This latter constitutes the working circuit. The main battery, which is in this circuit, cannot be short-circuited, owing to

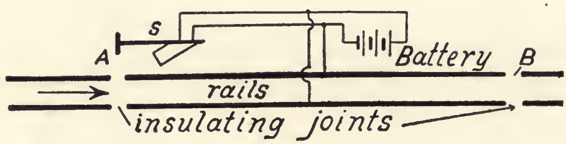


FIG. 9

the loss of energy which would result, the deleterious effect upon the cells, and the excessive sparking at the shunt contact, which latter would necessitate the use of unusually heavy or special circuit breakers. With a resistance in series, such as the line wire, motor, slot magnets, or other accessories, these precautions do not apply.

Considering the arrangement in Fig. 9, with a normally clear signal, *S*, whose current is obtained from a battery in shunt with the rails of the insulated track section, *A–B*, it is evident that as soon as a car, train, or locomotive passes along this section in the direction of the arrow, the resulting short-circuiting of the battery will deprive the signal of current, and thus throw the semaphore to the danger position. A train which is on any other section of the rails will not affect this signal, which therefore indicates only the condition of the section it immediately precedes. Such a circuit, while readily comprehended, is not commercially practicable for the following reasons:

(1) Too great a length of line wire is required.

(2) Unnecessary waste of energy, due to the short-circuiting of the battery.

(3) Adequate protection is not afforded (for reasons that will be clearer later).

(4) Too great a current loss will occur, due to the high difference of potential between the rails.

The principle of introducing series switch-contacts to throw a signal at danger when track switches in its block are opened into the home circuit of a signal is set forth in Fig. 10. In the block of *S* are three switches, *C*, *E*, and *G*, having three switch instruments, *A*, *D*, and *F*. Battery *B* energizes the operating mechanism of the home semaphore, *H*, through the successive relay points and the single pole contacts at *A*, *D*, and *F*. Therefore, should either of these switches be thrown open, the signal

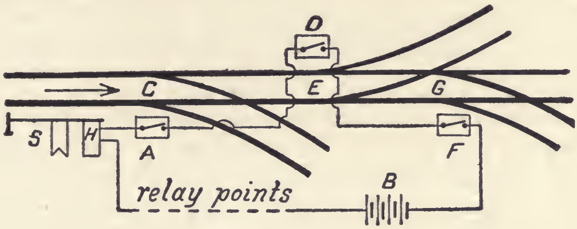


FIG. 10

circuit will be broken and the signal held at danger, regardless of the condition of the relay contacts.

In general, it is better to place the dependence of a safety condition or a danger indication upon the opening of a circuit rather than its closing. In the low-voltage circuits used in signaling, there is greater certainty in opening than in closing a contact. This is because a poor connection (or particles of dirt preventing the intimate metallic contact which is the prerequisite of a closed circuit) may introduce a sufficient resistance or air-gap to oppose the desired flow of current. As an example, the closed-circuit and open-circuit types of switch instruments may be cited. In the former, with an open switch, the track must be short-circuited; in the latter, the signal circuit must be opened to hold the signal at danger. The latter is obviously the most reliable, as a poor contact will merely mean a false danger

condition, while in the former, it will set up a false clear signal.

Nearly all existing types of automatic signals may be used in a semi-automatic sense; for example, placed at an outlying switch or interlocking scheme, and controlled by a line or track circuit from the nearest tower. Such a provision eliminates the use of cumbersome and costly mechanical interconnection, and involves no appreciable labor on the part of the operator in clearing or releasing. When the track circuit is used, the operation of this signal is taken from the immediate control of the tower operator, although the conditions required to be set up by train movement may class the signal as not purely automatic. The extension of these principles will be considered in Chapter V.

The conditions that may set up a false or dangerous condition in a signal system are manifold; but their actual occurrences few. The failures at danger can only wrongly delay a train; but failures at clear, by giving the engineer a proceed indication when such may not be safe, are the only ones that can really be termed dangerous. Such failures have in practice occurred on an average of one in a million movements. On a normal clear system, an average of one in about six hundred thousand has often been reported. Many such failures occur from inability of the moving system to move from its normal position. It is not, primarily, the external parts which are sensitive to such checks to movement, as they are thrown by a powerful force, and with sufficient inertia to remove a retardation; but the light control parts, whose motion is due to the expenditure of energy measured in thousandths of a watt.

Among the causes of false clear conditions are, fusing of control contacts, improperly counterweighted banner or semaphore, breaking of the color spectacles, rusting of sliding parts, foreign currents, residual magnetism in relays, imperfect contacts, dust or insects in relay boxes, crossing or grounding of wires, interconnection of wires with common, poor armature pivots, failure of clutches or locks to return, breaking of mechanical connections, and poorly insulated circuit wires.

The use of white as a clear indication is meeting with disfavor. This is due to the liability of a spectacle's breaking, or the chipping off of its color film. The adoption of green or red

for clear has many advantages, among which are the normal danger indication of a white light, except when a color spectacle is actually and properly before it, and the restricted conditions under which safety indications are given.

Failures at danger may be caused by a broken rail, bond wires rusted off or broken, rusty channel pin, high-current leakage between the tracks, broken wires in the relay, polarity reverser, track battery or signal circuit, exhausted track or main batteries, poor connections, unsoldered joints, broken battery jar, useless or poor connection in switch boxes or controllers, blowing of the protective fuses, failure of an arrester, broken line wires, short-circuiting of an individual or series of batteries, open circuit at motor commutator, failure of electric slots or locks, poor insulation, short-circuits in relays, and the depredations of mischievous persons.

As far as visual indication is concerned, the normal danger position is undoubtedly the best, and has been so recognized since the inception of mechanically operated semaphores; while argumentative opinion, from a purely electrical standpoint, also favors such a disposition. Formerly, standard normal clear circuits were more economical in initial installation, but this consideration no longer obtains.

Various signal engineers and others have from time to time regarded a certain modification or departure as ideal. Such arrangements, when actually applied, have frequently an ephemeral existence. In no specific instance has such unproductive effort been expended as in rail bonding. Railroad accessories undergo hard usage, and are subjected to extremes of weather, so that a scheme which seems temporarily of a revolutionary character is found hopeless after a few years of service. The greater part of the accessories introduced since automatic signaling began have been abandoned for this reason, so that standardization appears distant when viewed from the present.

Numerous attempts have been made to introduce protective arrangements supplementary to a visual system, in which the control of a train is taken temporarily from the engineman in case a danger signal is ignored or unapprehended. Fig. 11 shows an impracticable, though a generic form of such an accessory. When the home semaphore is in the danger position, it raises a finger or projection which engages with a pivoted

lever secured to one of the trucks of a train. This lever, *B*, is fastened to a valve, *A*, which is connected to the train pipe, *T*, of the air brake equipment by a flexible tube, *C*, the travel of this lever being limited by the quadrant *D*. Obvious reasons can be advanced against the application of such a device. We will take up in Chapter XVI a development of this principle, which has the merit of being in use.

The normal danger system admits of the employment of normally open-track circuits. This condition allows the use of open-circuit batteries (gravity cells cannot be employed) with consequent economy of operation. Instead of the customary

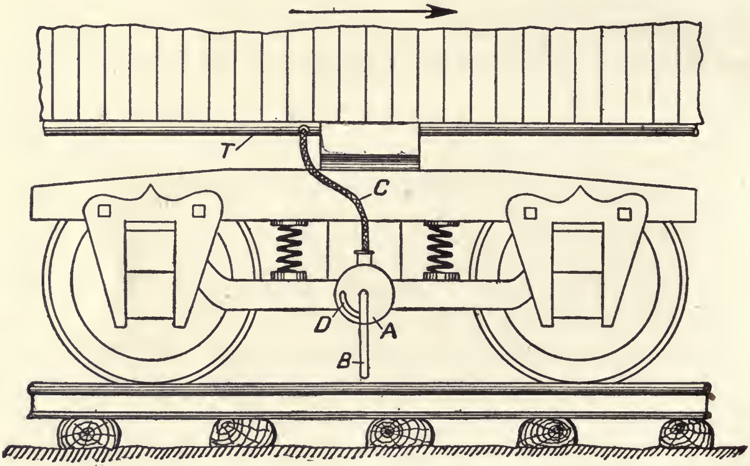


Fig. 11

two weeks' intervals between patching and renewing, it is possible to run six months. The circuits are closed in the preceding two blocks by the approaching train, and should anything be wrong in the block, the track relays will receive no energization. The continual heavy demand upon track batteries by the low-resistance track relays under a clear track condition has been heretofore one of the greatest disadvantages of signal installation.

In Fig. 12 a diagrammatic representation of relays and contacts, such as is used throughout this book, is given. *A* has one front (upper) and one back (lower) contact, each being a single-pole break, and so disposed that both cannot be in

simultaneous contact with the armature. *B* is a single front contact, and is more frequently applied than any other combination. *C* has two front contacts, with independent armatures; *D* two front and one back; *E* three front with common armature; *F* two front and two back; *G* three front with independent armatures; and *H* four front and four back, each having a double simultaneous break. In reality, these connections are usually effected by a single armature on each relay, but a more definite conception is afforded by representing as shown.

The application of automatic signals, by giving to trainmen the right to shift their trains at all reasonable times, renders imperative a positive knowledge of the condition of the track to which they are to proceed. Should a train be approaching this

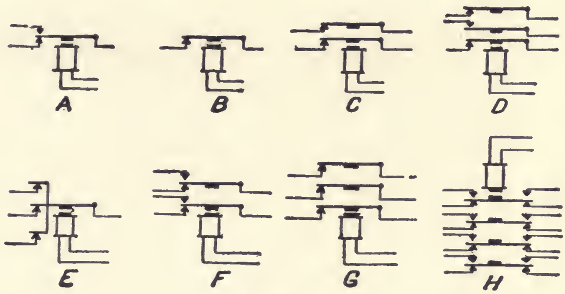


Fig. 12

block or is already within it, there must be some means of warning the trainmen not to open the switch. Should such a switch be opened, the main line signal must be held at danger, and information be conveyed to the trainmen that it has, and that the opening of the switch was the cause of such movement. This is now accomplished by means of a polarized indicator, as the neutral type cannot be thus applied; for, if a train enters the main block in question at the moment the switch has been thrown, the trainman will necessarily assume that he has been the cause of such indicator's movement, and unconsciously proceed to the main line without expectation of danger. Thereby delay would result to the train passing the main signal, if the latter's indication were understood by the engineman, but should the latter fail to note the condition of the block, a collision might result.

Primary cells are employed almost exclusively for the operation of automatic signals, because of their peculiar adaptability to the requirements of these devices. Although not nearly so economical as other methods of setting up currents of electricity, yet, when a small amount of energy is to be delivered continuously, or for long periods of time with extreme reliability, the question becomes not economy, but constancy of operation.

Thermoelectric devices, in which currents have been set up directly from heat, have been tried, but as yet have been found wanting, owing to their multiplicity of parts and the necessity of maintaining a flame continuously. Improvements along this line are anticipated, but may be hopelessly remote.

CHAPTER II.

SIMPLE CIRCUITS.

SIGNAL circuits admit of innumerable variations; and nearly every installation requires a special scheme of interconnection. There are, however, certain generic features adhered to which obtain in most cases. It is their differentiation which produces the seeming complexity when viewed as a whole. A number of simple circuits and their modifications will now be taken up.

The circuit diagram for an old style of disk signal is shown in Fig. 13. The main battery 11 is connected to the track, 15,

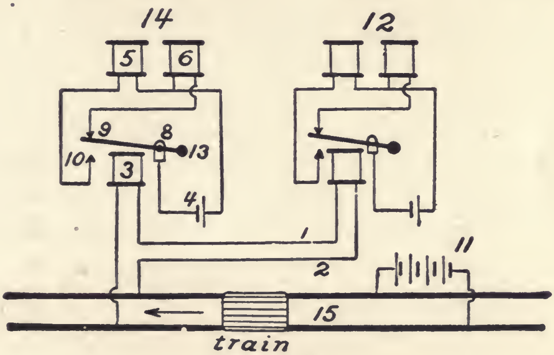


FIG. 13

and through the latter to two relays at signals, 14 and 12, in series with the line wires, 1 and 2. The signal connections are similar, and consist of a clearing electromagnet, 6, and a stop magnet, 5, whch are connected respectively to the connects, 9 and 10, of the armature of 3, the latter being pivoted at 8, and weighted at 13. With a train in the block, 11 is short-circuited, hence the relays are deënergized, their armatures touching the upper contacts, and closing the local circuit of 4 through 6, as shown. Thus, when the block is occupied, 6 is energized; when not, 5 is energized. A disadvantage of this method of connection is the great waste of energy when 11 is short-cir-

cuited, and the dangerous effects of a connection between line wires 1 and 2.

It frequently becomes advisable to control a distant signal from a manually or automatically operated home signal through the interposition of a circuit controller. Such an arrangement of circuits is given in Fig. 14, and provides for a power-operated

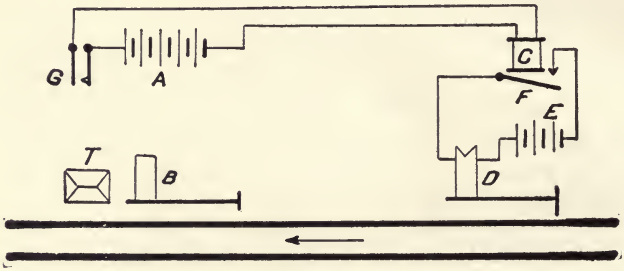


Fig. 14

distant signal. The latter, shown at *D*, is governed by the circuit controller, *G*. When the latter is closed (which will occur when the home signal, *B*, is thrown to the clear position by the operator at the signal tower, *T*) the line battery, *A*, sends current through the relay, *C*, at the other end of the line, which raises the armature, *F*, of the latter, closing the motor circuit of the local battery, *E*, and thereby throws *D* to the clear position.

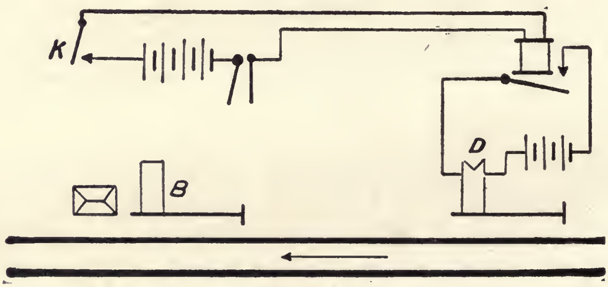


Fig. 15

If the above arrangement does not include sufficient precautionary measures, other functions are included which will prevent, in various ways, the conflicting of routes, false indications, and delay in train movement. It is the proper recognition of these factors, and their successful elimination, which produces the complexity often met with in signal circuits. In Fig. 15,

a switch, K, is introduced in the simple-control circuit given above, which requires operation by the tower attendant before the distant signal will assume the clear position. This condition is effected by including it in series with the line battery and relay governing the distant signal's motor circuit.

In Fig. 16 is shown a circuit arrangement which employs a

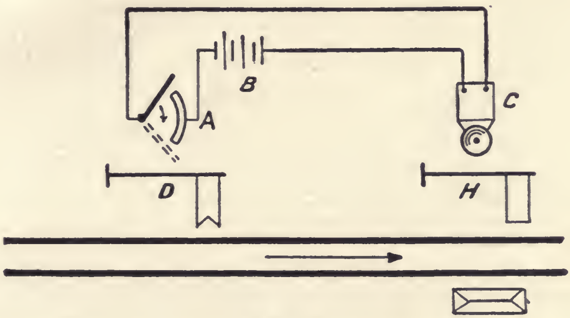


FIG. 16

vibrating bell, C, to communicate the desired announcement of the motion of a distant signal blade, D, to the tower operator. Motion of the semaphore produces a movement of the contact arm of the special controller, A, and consequently closes the circuit of the battery, B, in which C is included. This controller

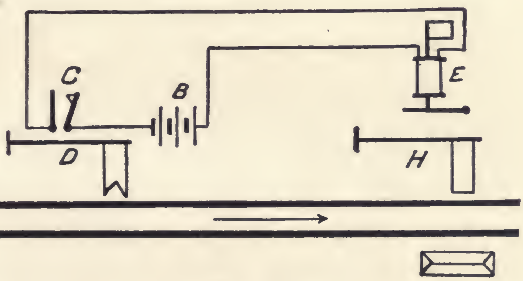


FIG. 17

is so arranged that when the blade is in either the extreme caution or clear position the circuit is opened. While the blade is moving, on the other hand, the circuit is closed. C may be a combination bell and indicator, or it may include a setting device.

A visual indication of the clear or caution position of a distant signal requires the use of an indicator, as shown in Fig. 17, at E.

When C is closed by the motion of the semaphore of D, the battery circuit is completed and the armature of E will be raised, in the type of indicator illustrated. Another type is used, however, which will indicate clear when its armature falls, requiring the use of a controller whose make and break is in the opposite sense to that shown.

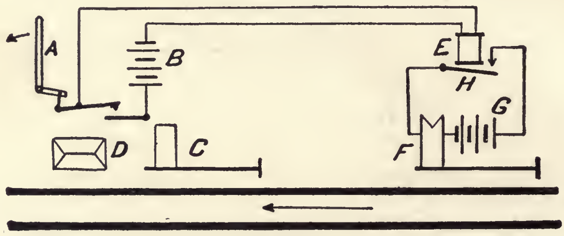


Fig. 18

In Fig. 18 we have a semi-automatic arrangement of circuits in which the circuit controller, D, is operated by the representative lever, A, of an interlocking machine. This lever controls by its mechanical movement a certain function, the electrical adjuncts being for another and distinct purpose, but of a concomitant nature, in the scheme of protection. When A is thrown in the direction of the arrow, the circuit of the line battery, B, is closed, thus energizing the distant relay, E, which, through its armature, H, sends a clearing current from the local battery, G, through the distant signal, F.

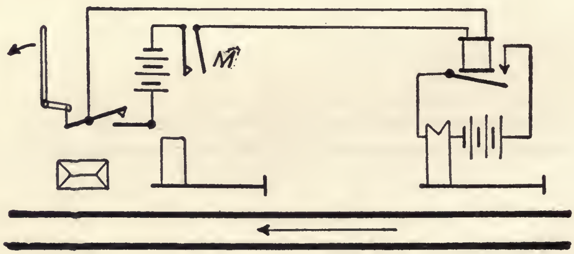


Fig. 19

In Fig. 19 the same principle is contemplated, but in addition a circuit controller, M, is employed, which thus prevents the distant signal from being cleared until the function the controller protects has been properly manipulated. This function, as will

be shown throughout this book, may have any desired application or complexity.

In Fig. 20 we have another semi-automatic scheme of connection for a distant signal; the bonded track circuit being used instead of line wires. The track battery, *T*, maintains a difference of potential across the section, *S*, and normally, by energiz-

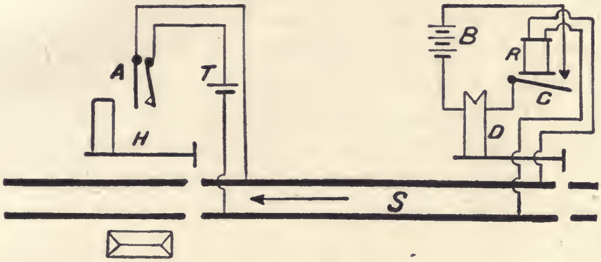


FIG. 20

ing the track relay, *R*, causes a current to pass from the local main battery, *B*, to the distant signal, *D*, through the armature, *C*. When *H* is cleared, the controller, *A*, is closed, and the reverse condition of affairs to that given in the figure obtains. Such an arrangement is more desirable, and less complicated than a line-wire system.

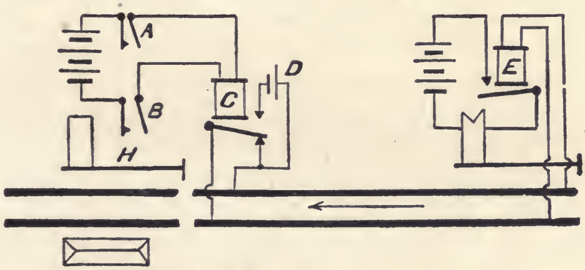


FIG. 21

The above distant signal cannot be controlled otherwise than through the movement of the home board. It sometimes is advisable to give the signalman authority to throw the distant board to caution without altering the clear position of the home signal. This is effected as shown in Fig. 21. When *H* is cleared, *B* will be closed as before. In addition, the hand switch, *A*, must be closed, or the track relay, *E*, cannot be energized due to the

position of the armature of *C*, and its connection with track battery, *D*. Thus, when both *A* and *B* are closed, the distant signal can be cleared. The armature of *C*, by short-circuiting the track, thereby performs the same function that a train in the section would.

In Fig. 22, *H* and *F* are normally clear home signals protecting the respective insulated track sections, 5, 4, 3, 2, and 1. The reason for such a division of a block is to increase the reliability of the track circuits by decreasing the effect of the track-circuit current leakage from rail to rail. The track batteries, *G*, are connected to the west or extreme end of each section, so that a train moving in the direction of the arrows will shunt the relays, the batteries discharging their current through the entire length of the rails. This protects against broken rails or open bonds,

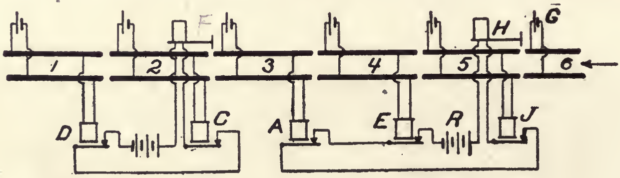


Fig. 22

This for double track. warns trains in rear.

by depriving the relays, such as *J*, *E*, *C*, *A*, and *D*, of current when such an open circuit occurs.

Under normal conditions, when neither of the sections is occupied by a train, the main batteries, as *R*, are in closed circuit with the signal mechanism, thus holding the discs in the clear position. When a train is approaching a signal, it is not affected, as the control functions remain the same. After entering the block, however, the relay, *J*, at the first section is deënergized, thus allowing its armature to fall, and open-circuiting the signal or working circuit and throwing the disc (or semaphore) to stop. This will occur on any section within the block, as the armatures and contacts are in series.

The functions introduced in a normal danger system, which clears the semaphore when the train enters the preceding block and causes it to remain clear until the train has left the block, irrespective of the number of sections it contains, are set forth in the diagram, Fig. 23. When the lower or back-contact armatures or points of relays, *M*, *W*, or *T*, drop, the home sema-

phore, *V*, will move to clear, providing the front contacts of *K* and *L* are closed. This occurs by reason of the back contacts of the relays, *M*, *W*, and *T*, at sections 3, 4, and 5 being connected in multiple, so that if one back contact closes, the same electrical condition is set up that would be the case if all or any other one of these contacts were closed. The front contacts of these relays

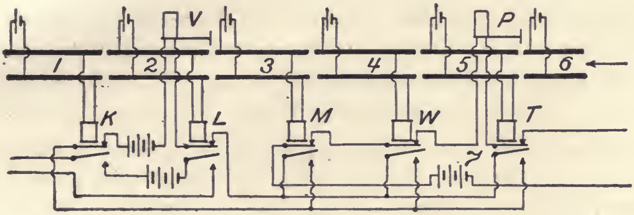


Fig. 23

are in series with the main battery, 7, which operates signal *P*, so that if either be open, the signal will remain at danger; a condition occurring when a train occupies either section. These relays thus become double functioned; and it frequently is possible to have all the contacts at a section box controlled by one relay. A modification or extension of this arrangement is used in all normal danger non-polarized line-wire systems.

In Fig. 24, 1 and 2 are two independent normal danger home signals, giving indications for trains bound west. The cut sec-

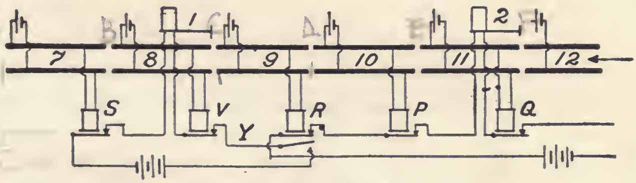


Fig. 24

tions, 7, 8, 9, 10, and 12, are connected to the respective relays, *S*, *V*, *R*, *P*, and *Q*, whose armatures, with one exception, close the circuits to which they are connected when the relays are energized. The lower, or back contact armature prong on *R* is normally open, and consequently keeps the main battery in open circuit. Its purpose is to hold the semaphore at stop when *R* is energized, and to clear the blade when *R* is deënergized. This

latter will occur only when a train occupies section 9, which may thus be termed a setting action. This clearing of the semaphore takes place under restricted conditions. If a train or broken rail occur in sections 7 or 8, 1 cannot be cleared by this armature falling, since the front contacts of either *S* or *V* will be open. Thus, if a train occupy section 8, the circuit will be opened at the armature of relay, *V*. The line wires, *Y*, are placed upon poles, and pass from one relay to the others. This arrangement is somewhat similar to the preceding, with the exception that the home signal is cleared only at the setting section.

Another simple, normal, clear home and distant (on the same mast) scheme of connection is shown in Fig. 25. The signals, *T* and *P*, each protect the track for two blocks, and are operated by the relays, *Q*, *W*, *B*, *O*, and *M*, each having two armature

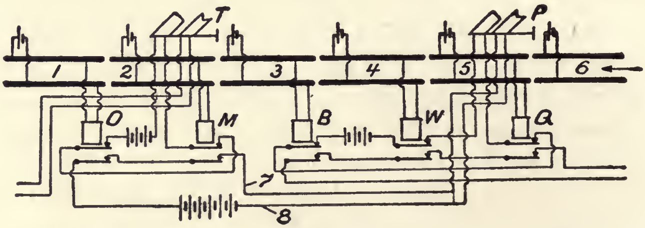


Fig. 25

contacts, the lower of which are connected to the distant blades, and the upper to the home blades. The home semaphore at *P* is controlled through the armatures of relays, *B*, *W*, and *Q*, which are connected to sections 3, 4, and 5. The distant is in series with the normally closed armatures of *O* and *M* at sections 1 and 2. These relays and semaphores are interconnected by line wires, as 7 and 8. It will be noted that the relays and track batteries are connected to opposite ends of each section, thus requiring the relay energizing current to pass along the rails, neutralizing the effect of fall in potential, and assuring the positive shunting of the relay by the train; at the same time guarding against broken rails.

The two general methods of throwing a signal member to danger when there is an open switch in the block are shown in Fig. 26. At sections 8 and 10 we have two switches, at which are placed the switch instruments, *B* and *F*. When the switch at

8 is opened, *B* short-circuits the track, and consequently the relay and track battery, thus setting up a condition analogous to that of a train in the section, the signal, *K*, being thrown to

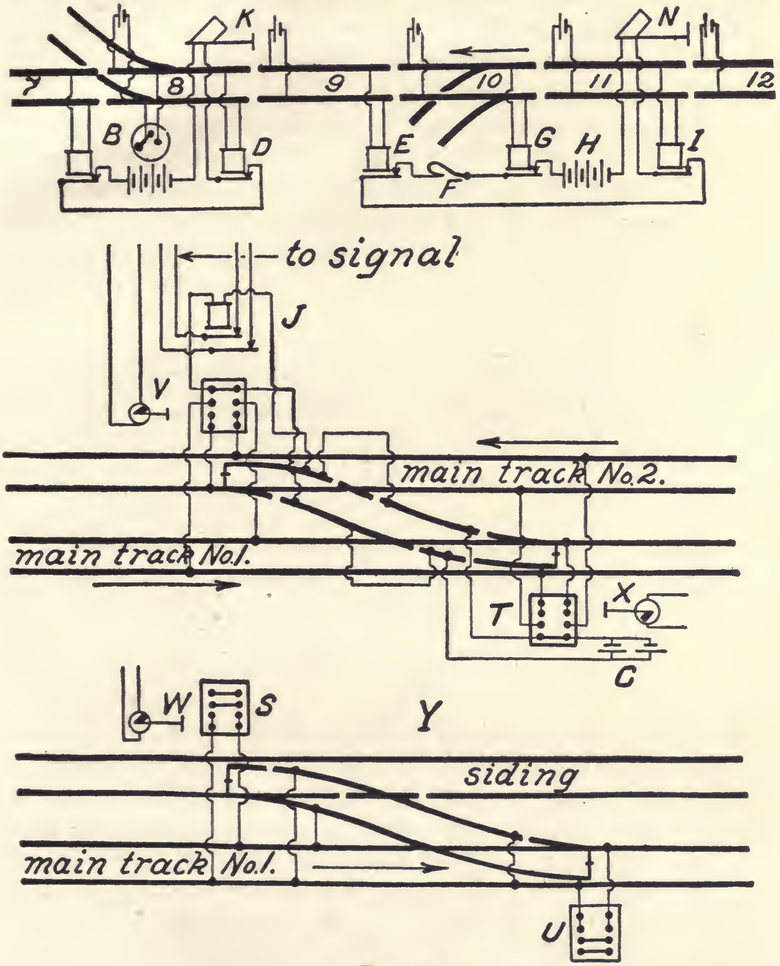


FIG. 26

stop in this case by the deënergization of *D*. This is effected by contacts within the switch instrument box which are connected to the rails of the track, so that when a revolving or rocking member is operated by a switch point, the rails become connected electrically.

At section 10, another arrangement is employed. *F* is a normally closed contact-spring, which is in series with the main battery, *H*, contacts of *E*, *G*, and *I*, and the home line of *N*. When the switch is thrown, *F* is opened, thus causing *N* to assume the danger position. Such a device is used only in line-wire systems, and particularly on normal danger circuits.

At *P*, the switch instruments, *T*, are applied to a cross-over; or from one main track to the other (trains moving in opposite directions), *V* and *X* are indicators, whose functions will be described later. Battery *C* supplies current to relay *J*, which current is cut off and the track rails short-circuited, when the switch is thrown. At *Y*, the same arrangement is applied to a siding, *S* and *U* being switch instruments, and *W* an indicator.

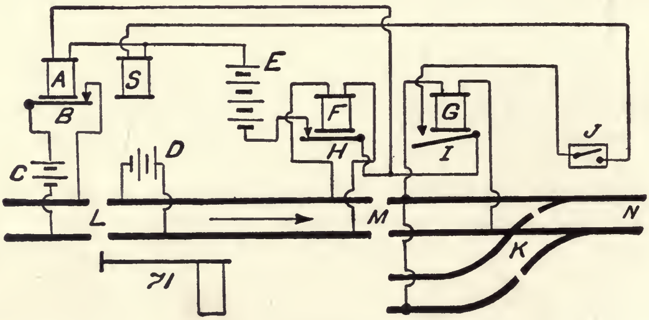


Fig. 27

A simple arrangement of overlap circuits in which distant signals are not used is shown in Fig. 27. Overlap was used in most early systems, to give an indication of a block's condition prior to the arrival of a train at the entrance of this block, thus eliminating the speed reduction that would be otherwise necessary in case a fog or other obscure condition prevented a clear view of the signal. The block, *L–N*, consists of two sections, *L–M* and *M–N*; in the latter an open switch, *K*, being present. Signal 71 protects this block, and is placed between signals 61 and 81.

The signal electromagnet, *S*, is in series with the armatures, *H* and *I*, of relays, *F* and *G*; main battery, *E*; and switch instrument, *J*, at switch, *K*. Since the latter is open, *E* cannot discharge current into *S*, because of the open circuit at the switch

instrument. Due to the rails at *K* short-circuiting the section, *M–N*, *G* is also short-circuited, and its armature is in the lower position. *F*, however, is still energized by the track battery, *D*, but does not affect *S*. As *H*, *E*, and *A* are in series, the armature, *B*, of the latter closes its contact and allows the track battery, *C*, to maintain a difference of potential across the rails of the section before *L–M*, or the second section of signal 61.

If a train were to occupy *L–M*, *A* would be deënergized, thus holding 61 at danger. Also, if *M–N* is occupied, 71 will be at danger, while 61 is at clear. Signal 81 is unaffected by train or switch movement in the block protected by 71, but operations in the block of 81 would affect 71 in the manner above shown.

Overlaps may have application equally well to normal clear or normal danger systems. Figs. 28 and 29 show the circuits used in a line-wire system for overlap on a single track for the former, with home signals only. Should a train occupy the section between 161 and 162, track relay, *C*, will be deënergized, and its armature contacts consequently opened. This open-circuits the clearing magnet or slot, *H*, and moves 162 to danger. The middle armature of *C* also open-circuits the operating magnet of 161, moving the latter to danger; 160 remains cleared, however, as *A* receives current from the battery at the next signal in its rear (in the same direction) through the line.

E and *F* are circuit breakers operated by the moving to stop of 163, and *I* is an indicator placed at the switch, *K*, in series with *F*. Hence, when *F* is closed, *I* should be at clear, since it receives battery current from *B* (through *J* and *K*). *L* is another switch indicator in series with circuit breaker, *M*, of 161. The remainder of the circuit is a repetition of the above.

At 1, in Fig. 30, *L* is a switch indicator placed at the main-line switch, *D*, which will indicate clear to a brakeman only when the home signals in the two preceding blocks, *A* and *B*, are at clear. This is effected through the use of circuit controllers or relay-armature front contacts at these signals, as shown. At 2, *G* is a polarized instrument which consequently has two (or three) indication positions. The controller at signal *E* determines the setting up of current in *G*, and the pole changers at *F*, the polarity of this current. In this fashion, the banner of *G* may either be in a central or side position, the language to the

brakeman being effected by its moving before one or more apertures in the mechanism housing.

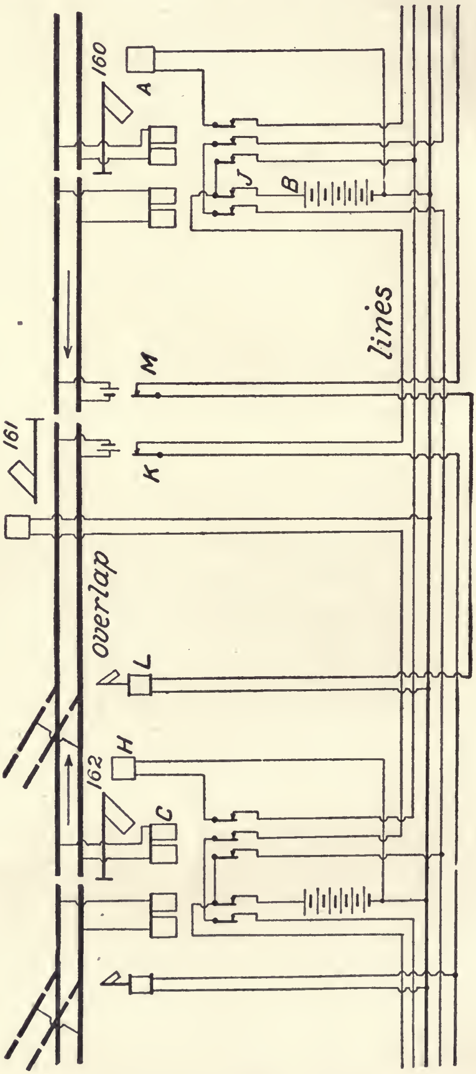


Fig. 28

Crossing signals are employed to warn pedestrians or teams at a highway or grade crossing of the approach of a train or locomotive. Fig. 31 shows a common circuit arrangement for such

a scheme, two insulated and bonded sections of track adjacent

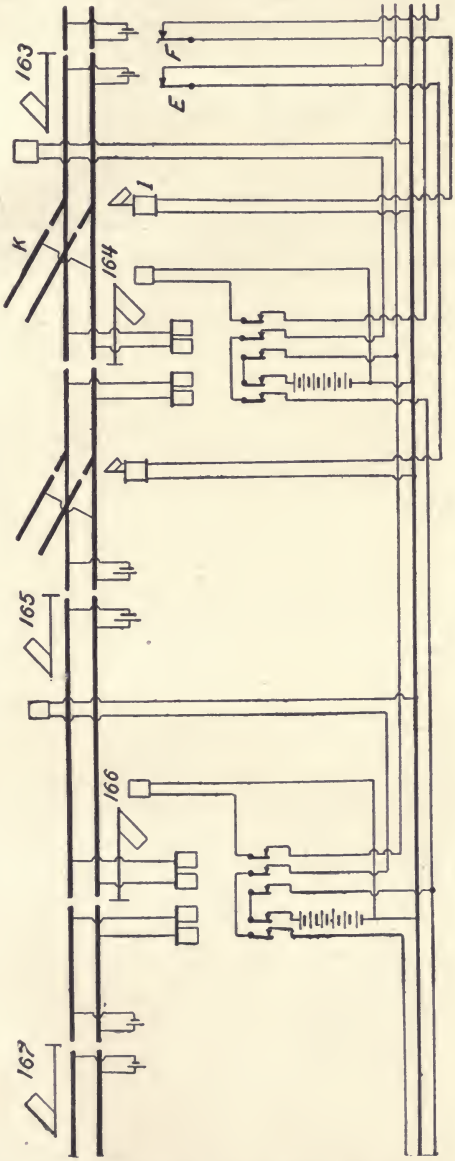


Fig. 29

to a highway forming part of the control elements, although line wires may also be used. These sections, 1 and 2, are electrically

isolated by the insulating joints, *G*, and energized by the track batteries, *A*. At the highway a signal, 3 (which contains the accessories diagrammatically shown), gives warning of train

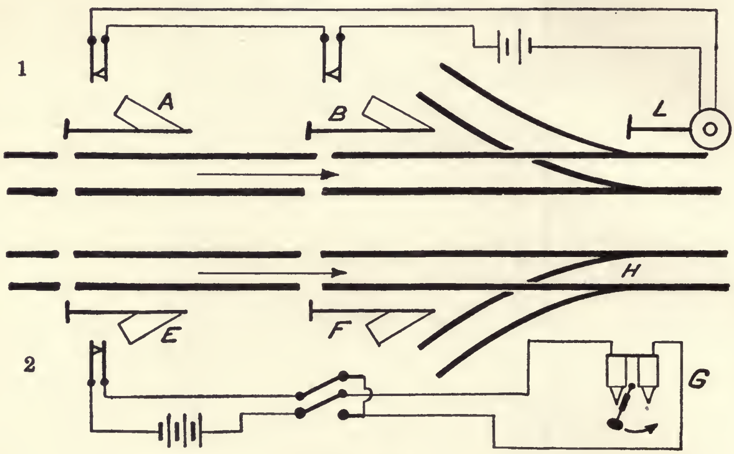


Fig. 30

movement by the ringing of a bell; which latter is sometimes supplemental to a small low-voltage incandescent lamp for night

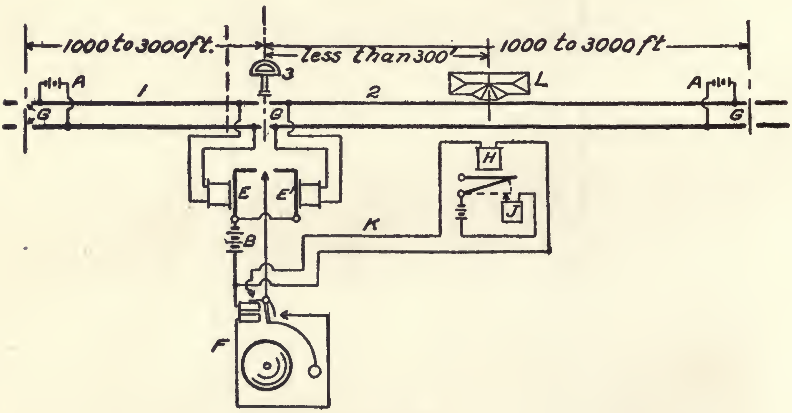


Fig. 31

indications. *L* is a station or block tower, provided with an automatic drop, *H*, containing an audible or visual indicating device, *J*, introduced in a local circuit closed by the release of

the contact armature. *E* is a relay having two interlocking armatures and separate magnets, so that if a train begins moving in either direction, the bell, *F*, will ring, but as soon as it passes the highway, *F* will cease to ring, due to the interference of the armature prongs which hold open the bell circuit. Thus, suppose a train moves from 1 to 2. *A* will be short-circuited and *E* deënergized, allowing a current to flow from *B* through *F*. At the first stroke of the bell clapper, a shunted current passes over the lines, *K*, and thereby operates *J*. As soon as the train passes the highway, the armatures of *E* and E^1 interlock, one holding the other away from the common contact, thus open-circuiting *F*. When the train passes out of section 2, E^1 is energized, thus retaining both armatures from interference.

CHAPTER III.

NORMAL DANGER CIRCUITS.

In the normal danger system, the indication members are always in the danger position, except when a train is approaching them. In the last chapter, a number of such simple circuits were taken up, hence preliminary details will be unnecessary.

Figs. 32 to 35 show consecutive normal danger line-wire signal circuits as applied to a single-track line with a passing side

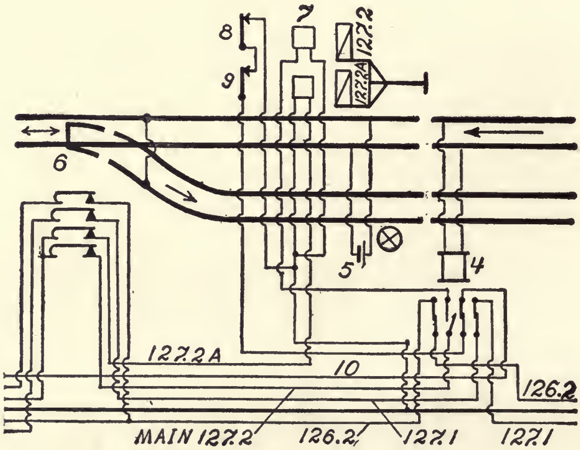


Fig. 32

track, and trains running in both directions. The signals are numbered according to miles and tenths of a mile, indicators being included at a siding. In Fig. 32, 6 is the switch leading into the main siding, while 4 is a track relay having four sets of armature contacts.

Should a train be approaching 127.2 (on the main track), the four-ohm track-relay, 4, will be short-circuited, thus causing all of its contacts to open except the second, which is a back

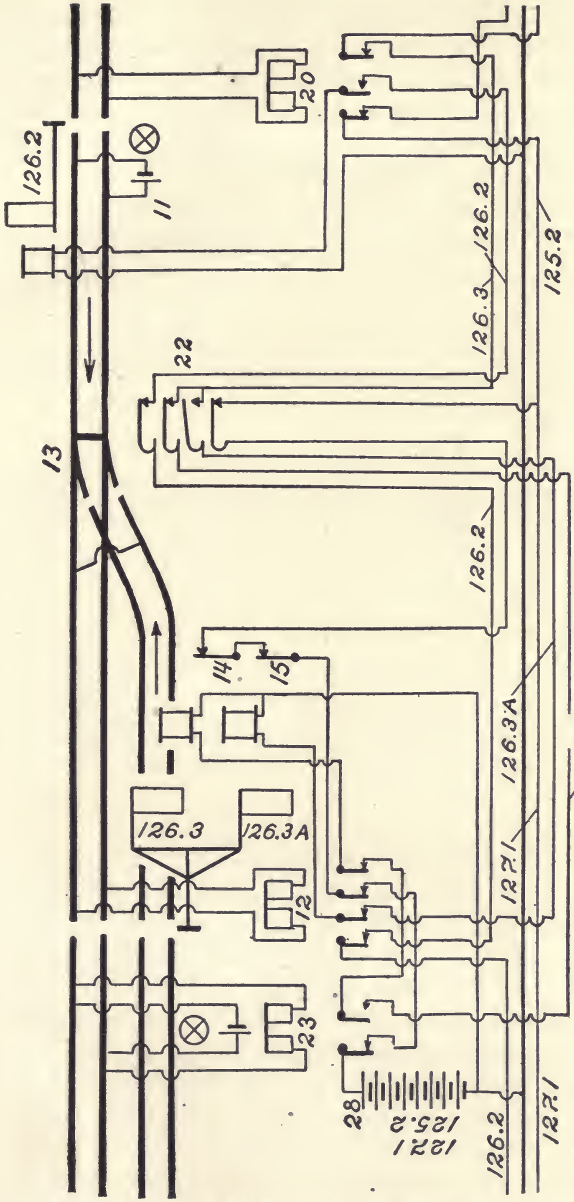


Fig. 33

contact. The closing of this latter causes a current to flow through the clearing arrangement, 7, main 127.2 line, lower contact at 6, and main battery at the preceding section, thus clear-

ing 127.2. The controllers, 8 and 9, which are operated by the semaphores at this signal, are in series, so that when either operates, line 10 is open-circuited. The track battery, 5, is connected to both the main and siding sections by the cross bond and insulating joint at 6; so that should a train be upon either track, it will be short-circuited.

In Fig. 33, 12 is a track-relay receiving current from 11, the latter also energizing the section constituting the end of the side track. The switch, 13, leading into this siding, operates

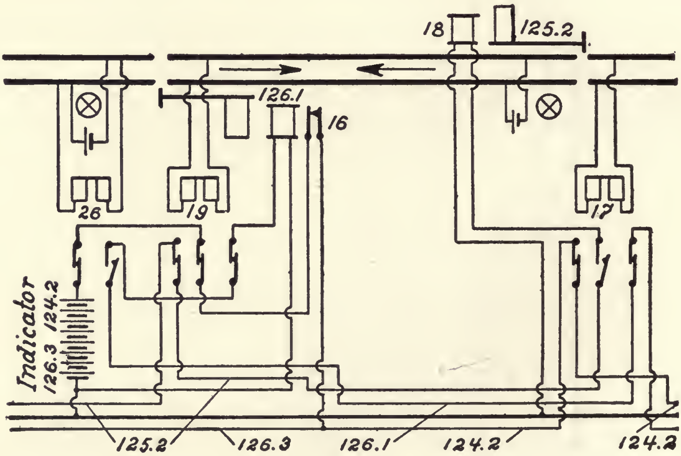


Fig. 34

four independent contacts, which are in series with the various line wires. The main battery and clearing magnets at signals 126.2 and 126.3 are connected to the common line wire, while 14 and 15 perform functions similar to 8 and 9.

Supposing that a train approaches signal 125.2, in Fig. 34, 17 will be short-circuited, thus closing the middle armature contact and clearing the signal through 18, by way of the common wire, line 125.2, first contact of 19, first contact of 20, lower contact at 22, 14, 15, third contact of 12, first contact of 23, battery 28, and returning to common.

In Fig. 35, 24 is an indicator wound to 800 ohms resistance which is connected to the indicator line-wire through the fourth armature of track relay 25 (of 4 ohms resistance), to the first armature of 17, to 16, middle armature of 19, first armature of

26, battery, and common line. The remainder of the connections are similar to those just considered.

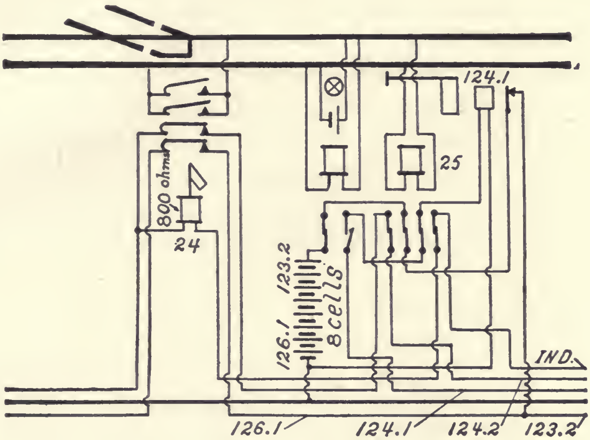


FIG. 35

In Figs. 36 and 37 the connections of a home and distant system for single-track with train movements in one direction

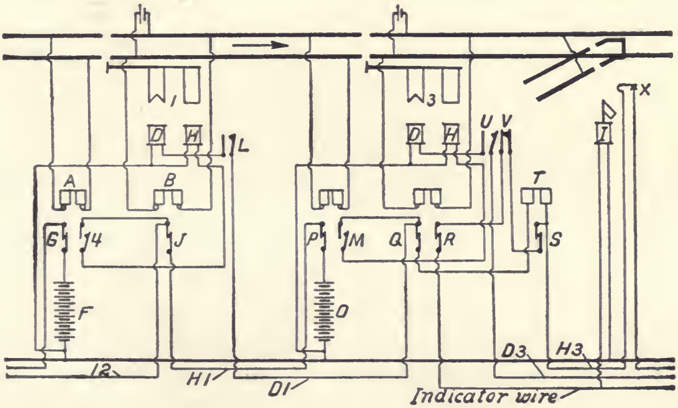


FIG. 36

are shown. At signal 1, *D* controls the distant semaphore, and *H* the home semaphore, both being mounted on a common mast. *A* and *B* are track relays, *A* having two armature contacts, and

B one. *F* is in series with the common line and armature *G*. 4 and *J* have a common connection to line 12, and are respectively connected to *H* and line H^1, while *L* is operated by *H* and controls the distant blade. With a train approaching 3, *B* and *K* will be deënergized; hence *J* will be opened, and *M* closed, *O* being disconnected from H^1 at both *J* and *P*.

When the block of 3 is clear, *Q* and *R* will be closed. *T* is in series with *H* and *M* at 3, and *D* at 1, through line D^1. *R*, *S*, and *V* are in series with the indicators, *I* and *W* (Fig. 37), through the indicator line-wire. H^3 transmits current from *Z* by way of the switch instruments, *Y* and *X*, and contact 8.

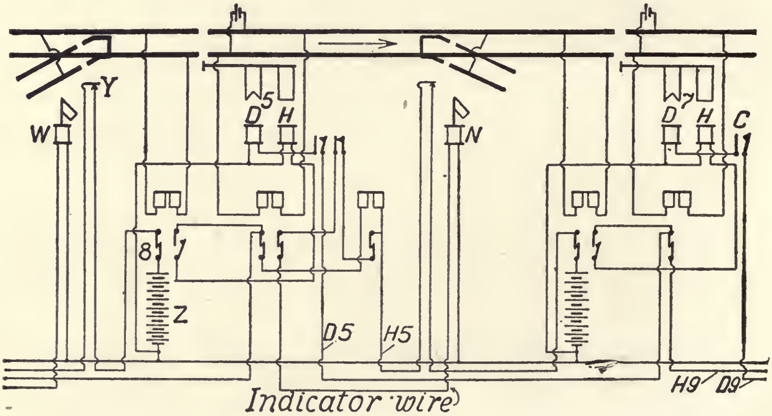


Fig. 37

At signals 5 and 7, a similar arrangement of circuits is evident, one side of the main batteries being connected as usual to the common line. At 7, a single normally open circuit-breaker, *C*, is provided, for the control of the distant head only.

Figs. 38 to 41 contemplate consecutive normal danger overlap signals such as are in use on the C. N. O. & T. single-track, with trains running in both directions; protection being afforded against both rear-end and head-on collisions. In Fig. 38, four signals, 1, 4, 15, and 17, with their connections, are shown. Four track sections, with batteries 3, 2, 18, and 16, and two relays, 7 and 6, constitute the control functions in this figure. 7 has three armatures, 13, 14, and 12, the first being connected to the main battery 5, the second to signal 4 through

a line wire, and the last to a battery line. Armatures 8, 9, and 10, of track relay 6, are connected respectively in series with main battery 11 and the common line, armature 12 and signal 15, also 14 and a battery line. Thus one side of each main

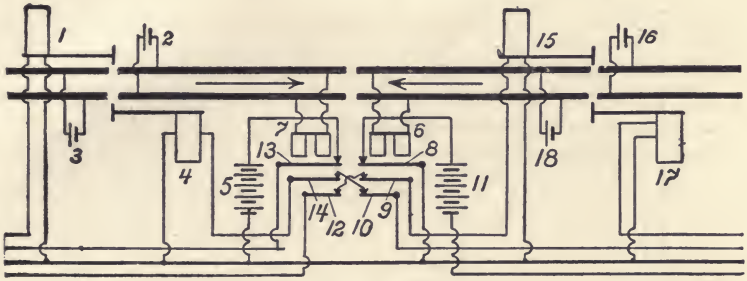


Fig. 38

battery and signal is connected to the common line, this applying to all four illustrations.

Continuing the track sections and line wires at a cut section in Fig. 39, two track relays, 36 and 37, have armatures (contacts) 38, 39, 40, and 41, 42, 43, respectively; while 44 and 45 are connected as in the preceding, 39, 43, and 40, 42, being interconnected in series.

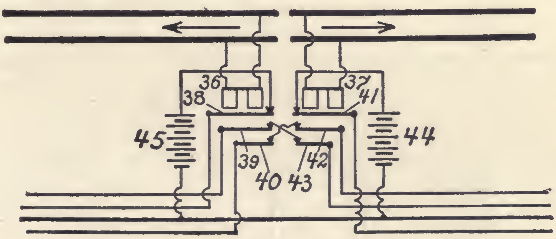


Fig. 39

In Fig. 40 a siding, 20, with switches, 21 and 22, is added, signals 19 and 23 being placed at this siding. Track relays 24 and 25, each having two armatures, 27, 26, and 28, 29, are added at the setting sections, their connections being similar to those already given. Switch instruments are not shown at 21 and 22, as they short-circuit the track in a manner similar to a train at these points, when open.

The track battery, 30, in Fig. 41, is in series with the armature, 32, thus introducing track circuit control. Signal 34 receives current from battery 44 through contacts, 41 and 29, while 35 is operated by current coming similarly over its line wire. The

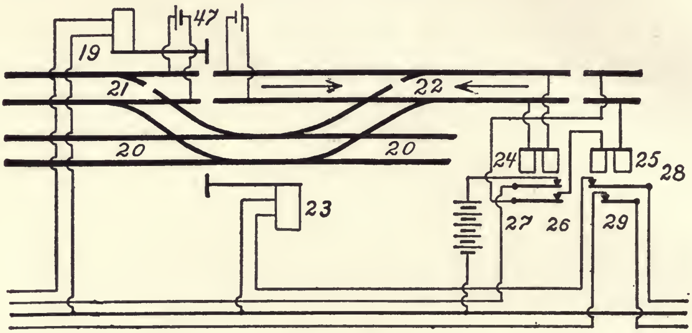


Fig. 40

main battery, 33, is in series with armature contacts 31 and an armature in the preceding block.

Suppose a train to be moving toward the west at 46 and that switch 21 is open. 47 will be short-circuited, and consequently

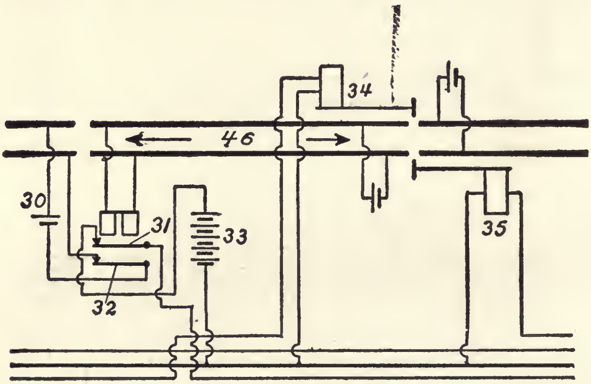


Fig. 41

37 deënergized, which causes 42 to fall, and holds 19 at danger, notwithstanding the fact that two sections intervene. As 25 is also demagnetized, 23 is held at danger by reason of the position of 28, while 29 open-circuits 44, and thus deprives 34 of current.

Another line-wire arrangement for home and distant on the same masts for one of the tracks of a double-track line is shown in Figs. 42 and 43. At the former, 1 is the distant line, 2 the home, 3 the common, and 4 the indication. Track relays 6 and 12 have a resistance of 4 ohms, 7 of 12 ohms, and 8 and 13 of 16 ohms; each of these having two sets of contacts. At section 9, for example, there are a set of binding posts, 25, which are

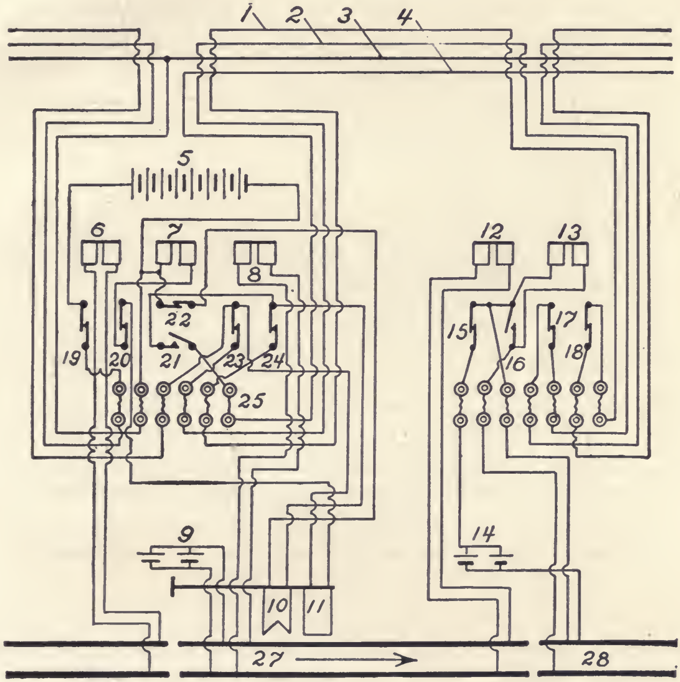


FIG. 42

mounted on the lightning arresters and connect to fuses. 16 and 21 are back contacts, while 15, 17, 18, 19, 20, 22, 23, and 24, are front contacts. 9 and 14 are track batteries, the latter in series with 15, and therefore in open circuit when a train occupies section 27. The short-circuiting of 12 also short-circuits 13 through back contact 16, the latter being in shunt with 13. When the train reaches section 28, however, 12 is energized and 16 opened, *B* receives current from 14 through the axles

of the train, which thus act as a single-pole switch. 5 is a main battery, 10 the distant semaphore, and 11 the home.

In Fig. 43 much the same circuit disposition exists, an indicator, 28, and two single contact switch instruments, 29 and 30, being introduced at the main-line crossover switches, 31. Both of these latter are also in series with the home line, 2, and the semaphore apparatus at 33, which is the usual practice for main-line switches, so that when either is open the home blade at 33 will be held at danger. One side of all main batteries and switch indicators is connected to the common line. The diagrammatic arrangement of binding posts is as it actually occurs in the relay boxes.

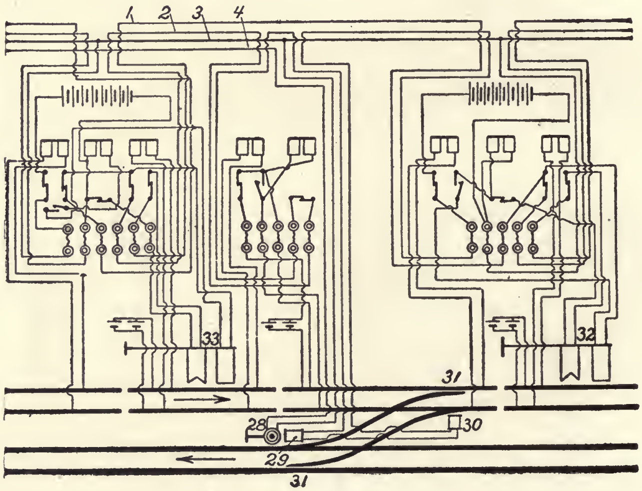


Fig. 43

A circuit arrangement for double-track application is given in Fig. 44. Two signals, 7 and 6, the latter a distant, protect a home block consisting of several sections, three of which are represented; the second containing a switch, 11. There are four main batteries, 1, 2, 3, and 4, which are, respectively, for operating the home-signal motor, control relays, switch bells, and distant signal motor. A vibrating bell, 10, is placed at the switch, which rings and consequently gives warning not to throw the switch when a train is in the second section from the latter. If the switch is thrown, however, the home signal

moves to the stop position. This will be announced when the section is clear by the continued ringing of the bell, which indicates, as will presently appear, that the signal has been set.

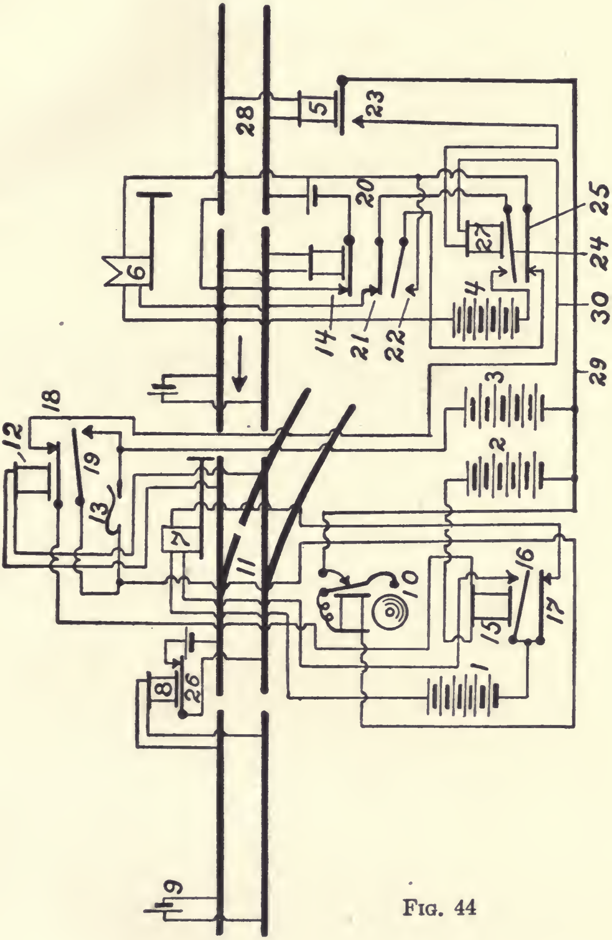


Fig. 44

When 7 is cleared, the contacts, 13, will be closed, thus ringing 10. 13 is in shunt with the armature, 19, of track relay, 12, while the armature contacts, 18, of this relay are in series with relays 15 and 27, battery 2, and armature 23 of the track section, 28, relay 5. Two line wires are used, and track circuit-control is

also effected by relays 8 and 14, whose armature contacts, 26 and 20, are in series with the track batteries.

Suppose a train enter section 28. Armature 23 will fall, thus sending a current from 2 through 15 and 27, through whose front contact armature, 24, a current passes from 4 to the distant-signal motor, and from 1 to the home-signal motor, by way of 16. The latter action causes the home-circuit controller, 13, to be operated, closing the circuit of battery 3 and the bell as above shown. (If more than one switch occurs in a section, the individual bells are connected in multiple.)

As the train enters the first section of 6, 14 is deënergized, and 4 is disconnected from 6, due to the action of the front contact, 21, even though 24 be closed. At the same time 22 is closed and 20 disconnects the track battery from 5, thus maintaining 23 in its lower position. If the block of 7 is occupied or dangerous, 5 does not control 27 and 15, since 12 open-circuits battery 2, the signals both remaining in the stop or normal position, and thereby hold the train.

As the train moves into the first section of 7, the latter is deprived of current by the deënergizing of relay 12 (should the block be unoccupied), due to the circuit of battery 1 being opened at 18. The bell, 10, continues to ring, however, until the train moves out of this section, due to its circuit being completed through 19, which is in shunt with 13, and performs the same function. When a train has indirectly deprived 27 of current its lower or back-contact armature, 25, closes an auxiliary circuit through the motor of 6, which short-circuits the latter, and, by causing the counter e.m.f. of the armature to set up a heavy current, effectually retards the semaphore, preventing the inertia of the moving parts from destroying any part of the system. In shunt with 25 is the armature, 22, of relay 14, so that, when a train occupies the first section of 6 and a second train is approaching, the retarding circuit will be closed in any case, which would not be the condition if 27 were energized by the closure of 23.

The motor-control relays are similarly connected for both signals, this connection, somewhat modified, being shown in Fig. 118, Chapter IX. Relay *A* is 27 in the last figure, the two armatures, *B* and *C*, being connected to battery *D* and a stationary contact, *F*. *J* is an electromagnet which retards the

motion of the armature by having a soft iron disk rotate between its poles, this disk being fastened to the armature. *E* is a contact piece moved by the semaphore's movement, and connects in an evident manner *I*, *H*, *G*, and *F*, at various parts of its stroke. In the position shown, *B* is connected to the motor, but not to the other side of the battery. If *A* is energized, *C* will connect *D* to the motor, this setting the latter's armature in motion. When *E* has passed over *F*, *D* is still connected to the motor through *G* and *H*. When *E* reaches the end of its stroke, *I* is connected with *G*, and a current passes from *D* through *J*, rapidly bringing the armature to rest, due to the eddy currents

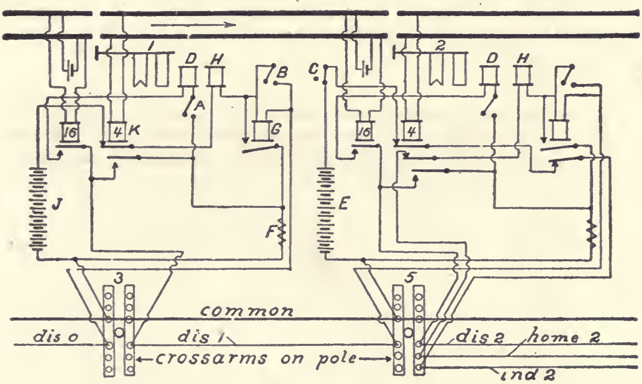


FIG. 45

set up in the disk and also to its friction on the magnet poles.

Fig. 45 is a delineation of a home and distant circuit for single track, with train movement in one direction. *A*, *B*, and *C* are operated when the home semaphore is cleared; *A* being in series with the local distant, *B* in circuit with the preceding distant, and *C* controlling the switch indicator; the latter being at danger when the home is at clear; *E* being the indicator battery. *B* is also in shunt with magnet *G*, whose armature, with the 150-ohm resistance, *F*, is connected to the common line, and the home-actuating mechanism, *H*. *G* is energized with the distant, at signal *O*, through its track-controlled relay armature. Hence, *H* is energized either from the preceding distant, or the local battery, *J*; in any case however through the front contact of the

four-ohm track-relay, *K*, the back contact governing the home at signal 2.

Fig. 46 continues the above, with a siding added. *P* and *M* are switch instruments, whose functions are to short-circuit both tracks, with an open switch; and to control the home semaphore at signal 2. *N* and *O* are indicators, in parallel, which are connected to both common and indicator lines. The main battery, *I*, operates the home semaphores at 2 and 3.

Figs. 47 and 48 (etc.) show normal danger circuits in conjunction with all-electric interlocking, as more specifically set forth in Chapter XIV. These occur at Union Street, Allentown, Pa., on the Lehigh Valley Railroad, at its intersection with the Allentown Terminal Railroad; and in addition to this, several sidings and branch lines. The working-circuit network emanates

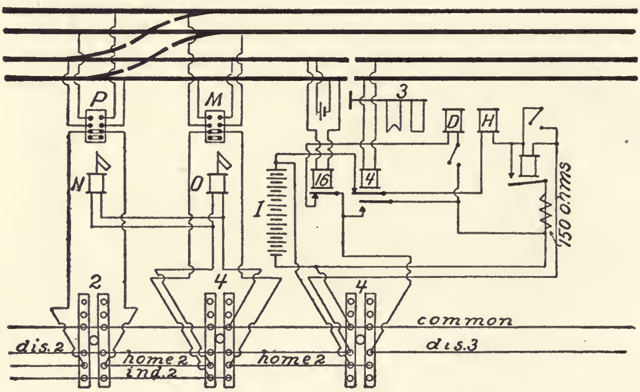
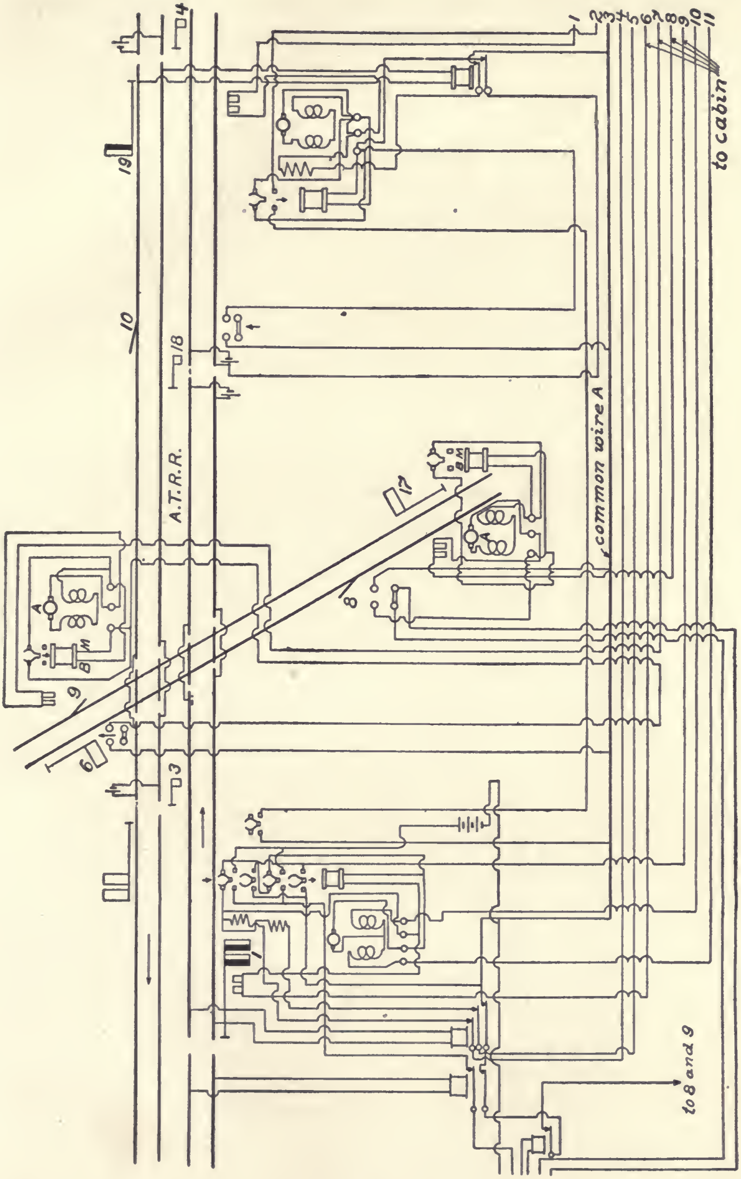


FIG. 46

from a signal cabin, within which is the interlocking machine and its accessories. Three separate common lines, *A*, *B*, and *C*, with relay control, are used. Motor armatures are designated by *A*, brake magnets by *BM*, and signals, switches, and derails by numerals. Dwarf signals, such as 4, 18, 47, etc., are used subsidiary to main and branch-line signals, and are of lesser size.

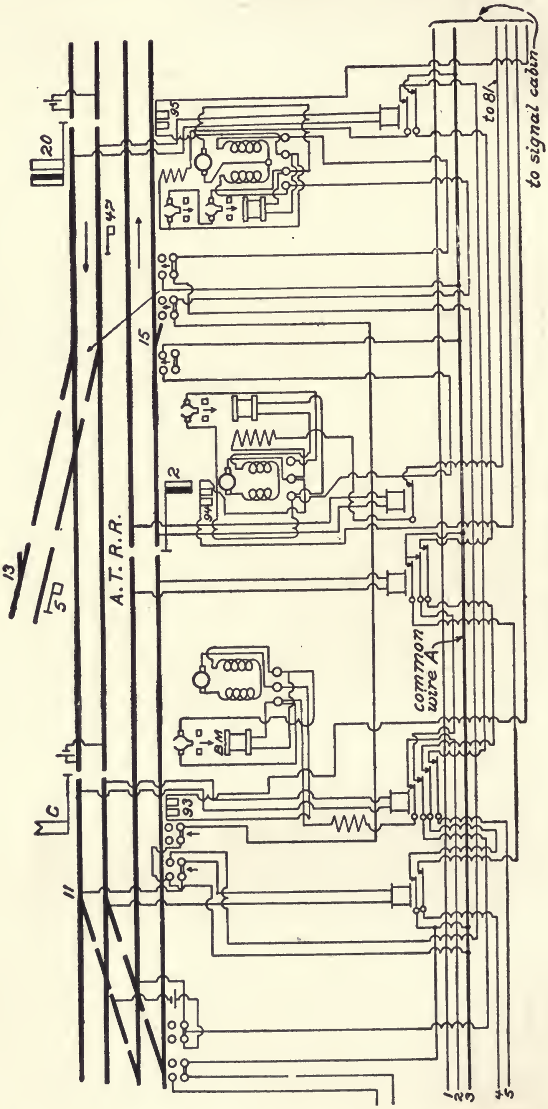
84 and 85 are vibrating bells under the control of track functions preceding those shown; 86 is a storage battery; 87 a west-bound distant indicator with shunted bell; 88 a west bound track indicator; 89 an east-bound track indicator; and 90 an east-bound distant indicator with a bell in multiple; 931 and



FIGS. 47, 48 (I)

932 are disk signals, whose "hold clear" coils have a resistance of 600 ohms; 91 and 92 are 16-c-p. 110-volt incandescent lamps,

controlled by signals 1 and 51 respectively, and form a visual indication at the tower of movement thereof.

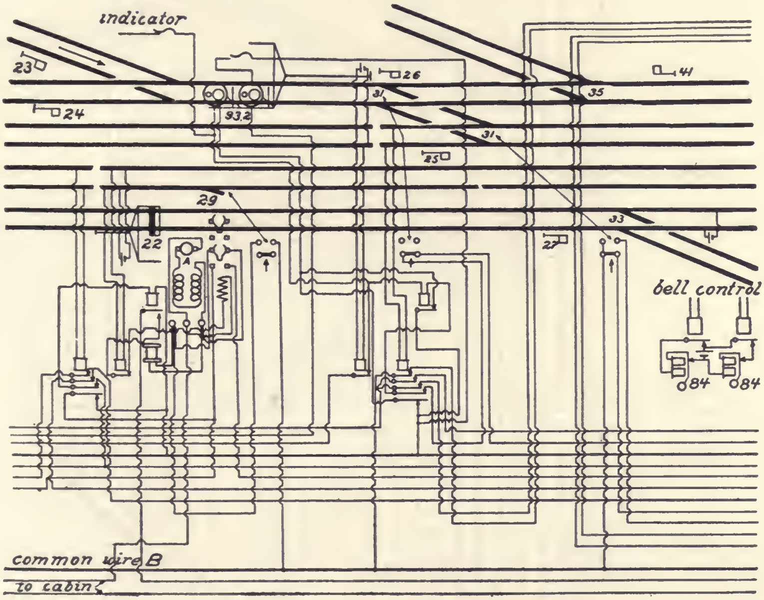


FIGS. 47, 48 (II)

93, 94, 95, etc., are slot magnets which allow the signal arm to return to stop when deënergized. The remainder of the cir-

cuits are common to those preceding, or will be more comprehensively evident on consulting Chapter XIV.

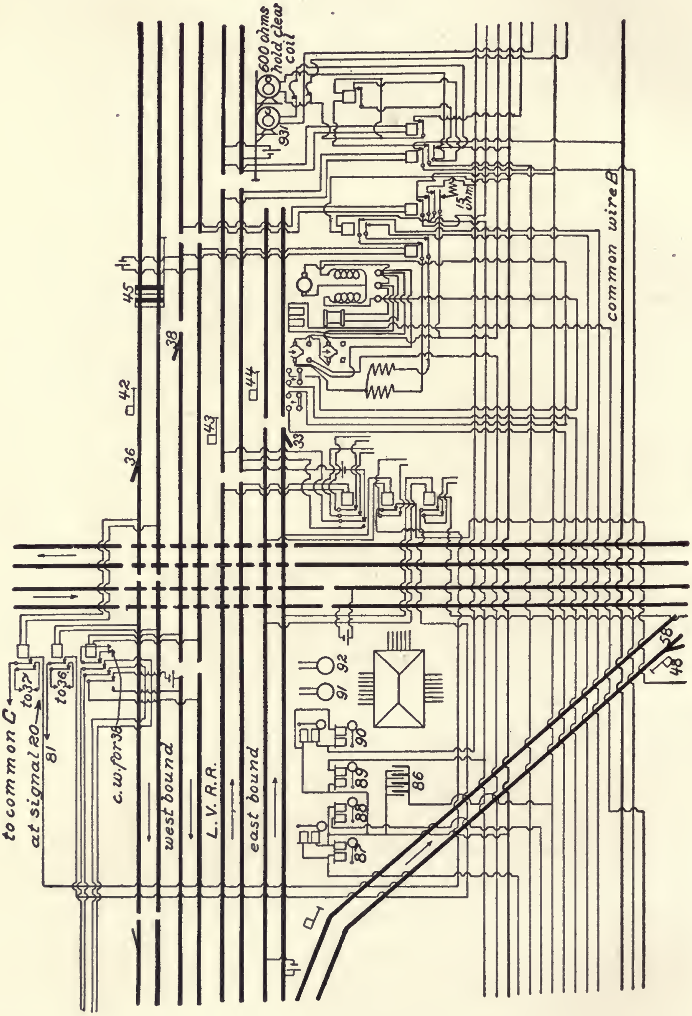
In Fig. 49 is developed a normal danger three-position signal circuit for six consecutive signals, with a train in each of the blocks of *K*, *P*, and *S*, and a crossover switch, *Y*, in that of *N*. The connections at all of the blocks are similar; with the exceptions of the functions, *D*, *E*, *F*, *G*, *H*, and *J*, which are introduced for variation. Describing the apparatus at *K*, we have,



FIGS. 47, 48 (III)

the three-position signal relay, $3P$, track relay, *T*, motor, *M*, clutch-magnet, *C*, lock-magnet, *L*, main-battery, *B*, and the contact-arrangement, *Z*, operated by $3P$. This latter changes the interconnection, so that at each indication position we have a proper circuit-arrangement. Three stages of contacts exist: (1) when the semaphore is at clear, and 4 is connected to 5, as at *W*; (2) when the blade is at normal or danger, as at *X* (a similar condition obtaining when the arm is at caution, as at 7); and (3) when the semaphore is at danger with a train in its block, as at *Z*; and 1 is in contact with 2.

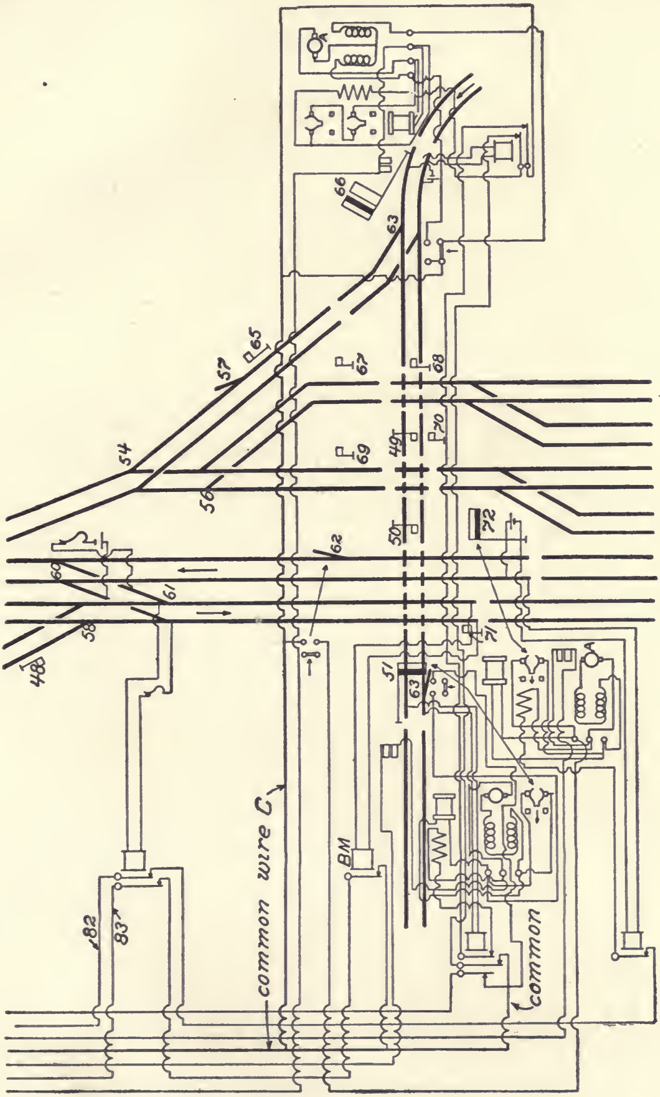
It should be noted that the $3P$ relays are in multiple with the succeeding main batteries through the front-contact armatures, U, of the track relays; and that in order to energize the



Figs. 47, 48 (IV)

motor, clutch, and lock magnets it is necessary for the back contacts, R, of the preceding relays to close. This energization will not occur unless all other conditions are normal, an impossi-

bility if the track is short-circuited or open by any cause. The front contact, A, of the $3P$ relays is for energizing the lock



FIGS. 47, 48 (V)

magnets, and then only by way of R and at such times as the motor and clutch magnets are not in circuit. In this case three line wires are necessary, as 8, 9, and 10.

Fig. 50 gives the circuit connections peculiar to a control scheme for semi-automatic home, advance, and distant sema-

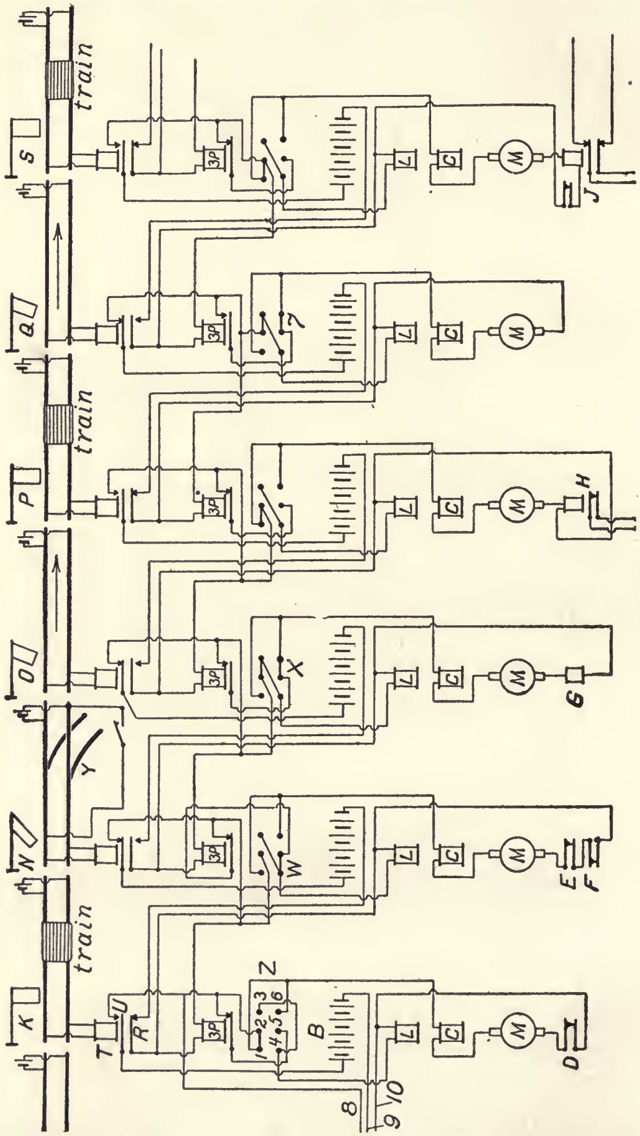


Fig. 49

phores. The home blade, *N*, is controlled by lever 1, and when the latter is thrown, contact *C* is closed; and, if *D* be then

momentarily pressed down, *B* will be energized by the shunting of battery *L*. This causes a current to pass through *A*, providing *K* is on closed circuit, even though *D* be released. When lever 2 is thrown, *E* is closed, and if *F* is then closed for a moment,

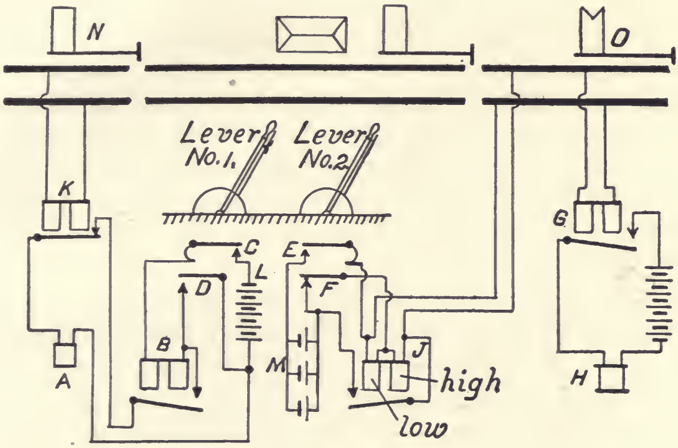


FIG. 50

a current will pass through the low-resistance winding of *J* from battery *M*. This raises its armature, throwing in circuit the high-resistance winding and the shunt-track circuit of the distant *O*, energizing *G*, and, in the proper sequence, *H*.

CHAPTER IV.

NORMAL CLEAR CIRCUITS.

In all normal clear systems, the signal semaphores or disks are in the clear position at all times except when a train is in the block protected, or an otherwise dangerous condition exists. This implies that the clearing or retaining devices are normally in circuit with the power battery, and that their control is primarily effected with front relay contacts.

In Fig. 51 a diagram of one form of polarized system of normal clear signals is given. *C* is a two-arm semaphore signal, *E* being

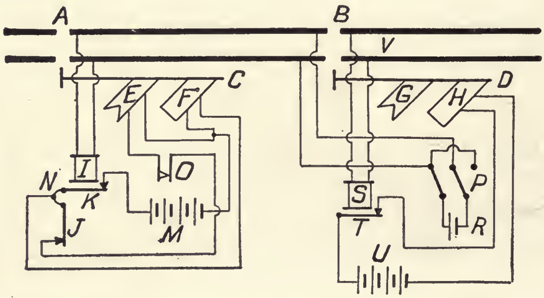


Fig. 51

the distant, and *F* the home blade. *F* indicates the condition of block *A–B*, to one end of which the polarized track relay, *I*, is connected, this relay deriving current of a given polarity from the track battery, *R*, at *B*. This circuit is through the rails of the track and the pole-changing switch, *P*, which is actuated mechanically (in the direction shown by the contacts) by the home blade, *H*, of signal *D*.

The distant blade, *G*, is not shown connected, to simplify the circuits; while the pole changer is omitted at *C* for the same reason. Relay *S* is connected across section *V*, in the block controlled by *H*, and derives current from a battery at the

other end of this block, a polarity changer being also interposed.

Relay *S*, through the armature *T*, and a front contact, controls the flow of current from the signal battery *U*, to the home blade, so that when *S* is deënergized *T* falls, and by opening the circuit of *U*, causes *H* to move to the danger position.

If a train occupies the block between *A* and *B*, *R* will be short-circuited, thus deënergizing *I* and allowing the neutral armature, *K*, to drop, thereby open-circuiting the signal battery, *M*, and causing *F* to move to the danger position. *O* is a series switch open-circuited mechanically by the motion of *F*; hence *E*, deriving current from *M* through this switch, moves to the caution position.

The neutral armature, *K*, is connected to *J* by the jumper wire, *N*, *J* being the polarized armature of *I*, whose direction of motion, and consequently of contact, depends upon the polarity of the current which *I* receives. With *P* in the position shown, *J* will be in contact with its contact finger; but if *P* be reversed, *J* will be on open circuit. This latter condition will evidently occur if a train be in section *V*.

When the train passes out of the block of *H*, it moves to the clear position, by the action of relay, *S*, which restores current to this blade. This causes a shifting of the pole changer, which returns to the position shown in the diagram. The reversal of polarity causes *J* to move to its normal position, thus restoring *E* to the clear position.

Fig. 52 shows diagrammatically the arrangement of a block consisting of two insulated track sections, *A–B* and *B–C*; the home and distant semaphores being on separate posts. Such an arrangement is employed where the blocks are of considerable length, and wherever it is most desirable to locate the home and distant blades on independent posts, the distant semaphores being placed between the home signals.

Upon a train's entering the section, *A–B*, the armature, *H*, of track relay *G* falls, thus open-circuiting the main battery, *T*, and causing *D* to move to the danger position. When the train enters the section, *B–C*, the track relay *I* is short-circuited, thus allowing its armature, *J*, to fall, and, by open-circuiting track battery *M*, depriving section *A–B* of battery current. Thus *G* remains deënergized while *D* remains at the danger position.

The presence of the train in section *B–C* also allows the neutral armature, *K*, to fall, hence *E* moves to the caution position, being deprived of current from the main battery, *S*.

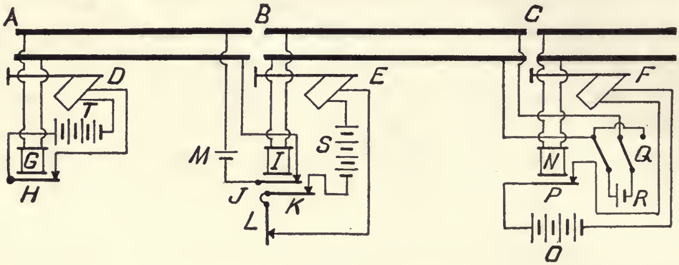


FIG. 52

The polarized armature, *L*, is not directly affected until the train has passed the insulating joints at *C*, when, by *N* being short-circuited, *P* falls, thus moving *F* to the caution position by open-circuiting the main battery, *O*. The motion of *F* throws the polarity reverser, *Q*, over, thereby reversing the polarity connections of *R* to the rails of section *B–C*, and causing *L* to move away from its contact, maintaining *E* in the caution position. This will continue until the train passes out of the section controlled by *F*, when *E* will return to clear.

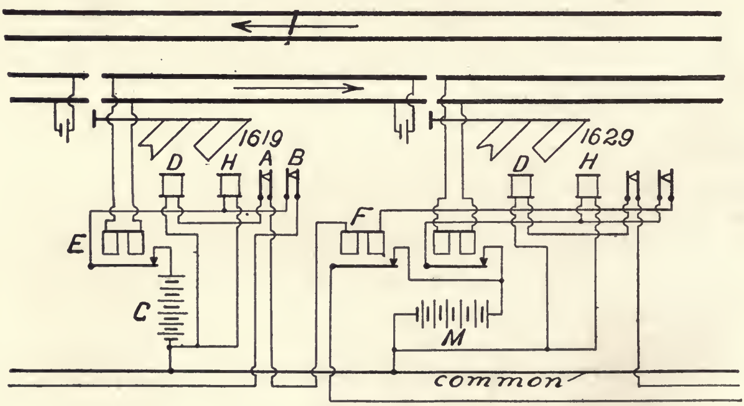


FIG. 53

The consecutive connections of home and distant normal clear signals for one side of a double-track line are shown in Figs. 53 and 54. At signal 1619, *D* operates the distant blade and *H*

the home semaphore. In reality, these are motor-slot magnets, the motor itself being operated through an auxiliary circuit, which consideration, however, does not affect the fundamental connections. *A* and *B* are closed by the clearing of the home board, *A* being in series with the distant at 1619, and *B* in series with the distant at 1609 through the line wire. *H* is operated by current from the power battery, *C*, through the armature of track relay *E*. Hence, when the block of 1619 is occupied, *H* will be deprived of current, and *A* simultaneously opened, thus throwing both semaphores to the stop position.

The connections at 1629 are similar to the above, a series relay, *F*, being added, however, whose armature is raised when

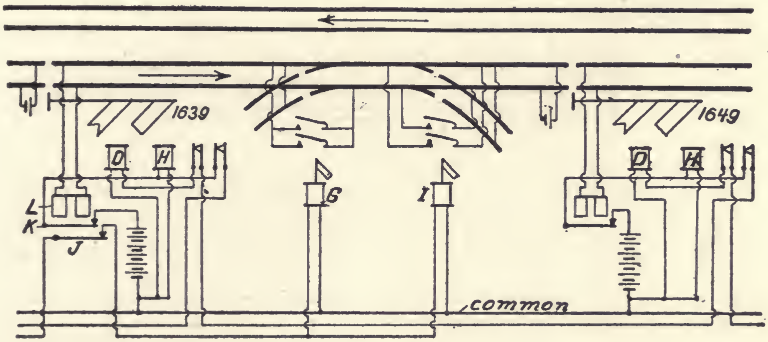


Fig. 54

current passes to the switch indicators, *G* and *I*, in Fig. 54, through the common and indicator line-wires, armature *J* at 1639, and battery *M*. The remaining circuits at 1639 and 1649 are practically identical with the preceding. In both diagrams a common line-wire is introduced. This is the usual practice with line-wire systems, one side of the main batteries and switch indicators being connected to it, thus economizing on the extra copper that would otherwise be required.

In Figs. 55 and 56, 2, 4, 6, and 8 are normal clear home and distant signals controlled through line wires and applied to one of the tracks of a double-track railroad. But one track relay is used in each block, the contacts, *C*, of these relays being in series with the home operating device. *B* is a distant contact in series with the circuit breaker, *E*, operated by the home sema-

phore and controlling therewith the distant blade of the preceding signal. Track circuit-control is introduced at *T*, Fig. 56, this arrangement being generally interposed in long blocks

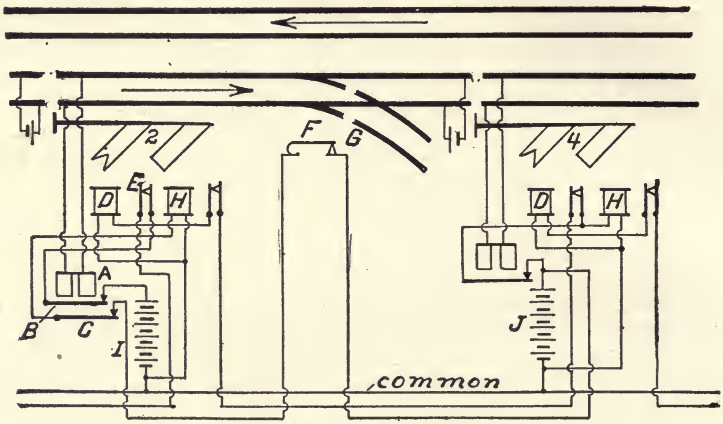


Fig. 55

having necessarily several sections. The front contact of the relay, *T*, is in series with the track battery, *M*, the back contact being in shunt with the latter. Hence, when *T* is energized,

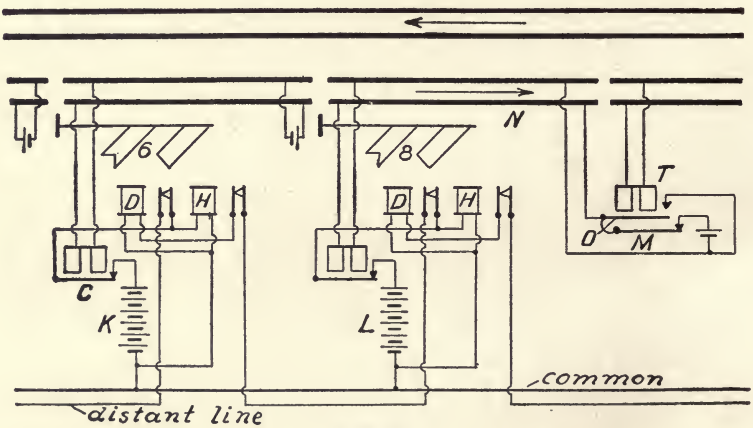


Fig. 56

M will be connected to and energize section *N*, while when *T* is deprived of current, the back contact will short-circuit the track at *N*, the front contact simultaneously open-circuiting *M*.

At the switch, G, a contact, F, is arranged, so that when the switch is open H will be deënergized and the home and distant blades at signal 2 thrown to stop. One side of each of the main batteries, I, J, K, and L, is connected to the common line-wire, as in the preceding case.

Figs. 57 to 62 show the standard normal clear overlap line-

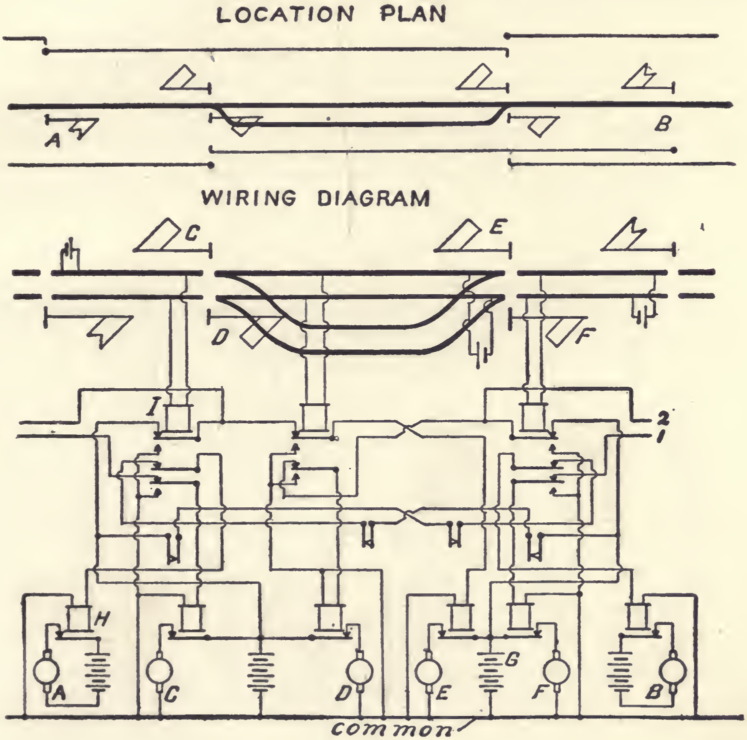


FIG. 57

wire circuits on single-track for east- and west-bound movements on the Southern Pacific.

In Fig. 57, A and B are distant signals indicating the track condition when approaching a station siding. The location plan shows the extent of the sections protected by the semaphores and the arrangement of the signals. Home signals, C, D, E, and F, are operated by the motors and accessories having corresponding letters. A, for example, is controlled through the

armature of relay *H*, the latter being connected to main battery *G* through a front contact of track relay *I*, and the normally closed circuit breakers at *D* and *F*, by way of one of the distant line wires.

In Fig. 58 a similar arrangement is employed, a cut or relayed section being introduced. This changes the extent of the control of the home signal preceding *J* in the location plan, and

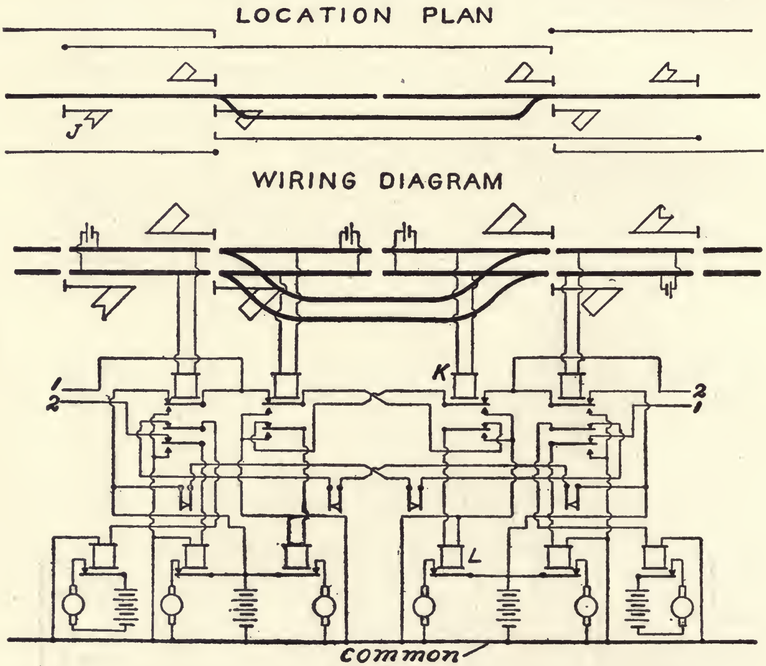


FIG. 58

interposes a track relay, *K*, having two front and two back contacts. The front points extend the function of the home line wires, the back points short-circuiting *L* and connecting one of the home lines to common.

In Fig. 59 overlaps are introduced at the west end of a station siding, and a distant signal at the east end. The distant control-line, *M*, is in series with the home-circuit controllers, *N* and *O*, current being derived from the main local battery, *P*, an independent local battery, *Q*, operating the mechanism. It will

be noted that the negative sides of the main batteries are connected to the common. This precludes the possibility of dissimilar polarity, and the consequent wasteful discharge on confusion of the circuit wires.

The converse of the above appears in Fig. 60, a distant signal being placed at the west end (in this book, the east is always at the right and the west at the left hand side, as will occur when

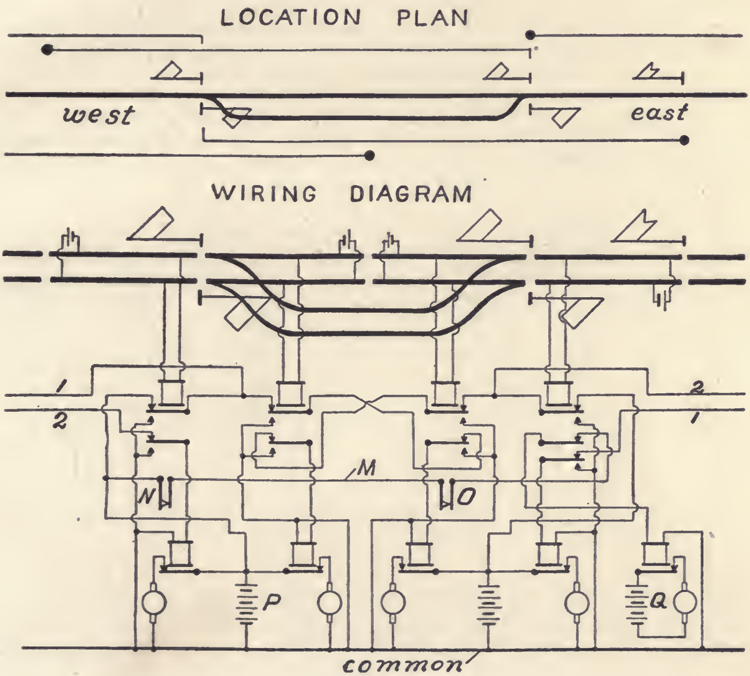


FIG. 59

the reader is facing north), and overlap at the east end. The independent working circuit is at *R* in this case, relay *S* having three front and two back points, the latter connecting to common. The front points clear the signals for one direction of train movement, and the back points are for the opposite sense, also completing these same control circuits.

Figs. 61 and 62 show the circuit arrangements between stations, with overlap. In the former, home signal *T* is controlled through line 1, and *U* through line 2. The working cir-

cuit, *V*, of the former is independent, that of the latter being connected to the common, as are all the track-relay back points. In Fig. 62 a relayed section only is shown, the line wires being simply broken at the relay contacts, a location diagram being unnecessary in this case. As before, the back contacts are connected to common, and close the preparatory control functions.

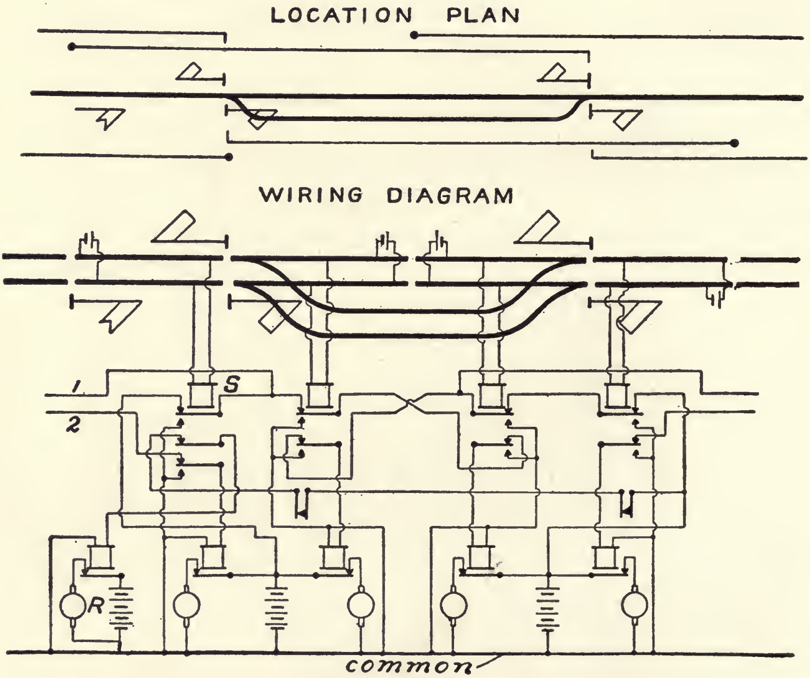


Fig. 60

Figs. 63 to 66 show normal clear motor-circuits and signal arrangements on the Missouri Pacific, the mile posts and signals being numbered from the terminal at St. Louis. Home and distant semaphores are placed on separate masts and controlled through line wires. The motor connections only are represented, but of course slot magnets are in parallel with the main batteries, the motors not being in circuit except when clearing takes place.

At home signal 142, a circuit controller is introduced, which closes the track relay upon itself when the switch is thrown,

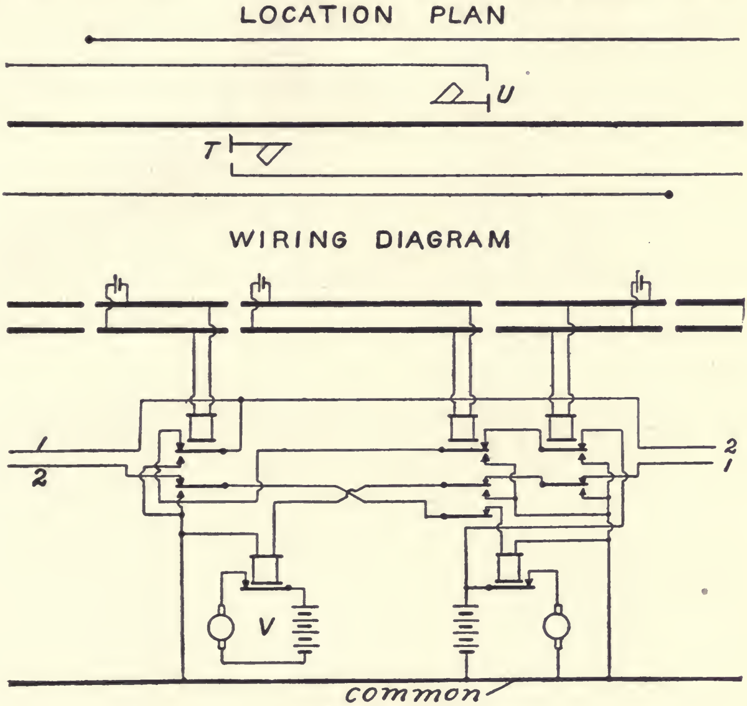


FIG. 61

and connects the relay to the track when the switch is returned. In the semaphore's stop position, also, a circuit breaker in series

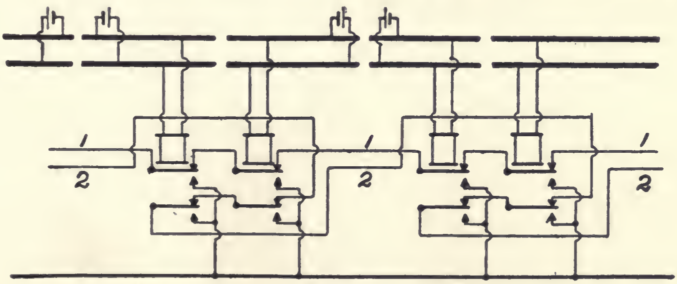


FIG. 62

with the motor at the distant signal, 142–*D*, is closed, clearing the latter by energizing the motor relay.

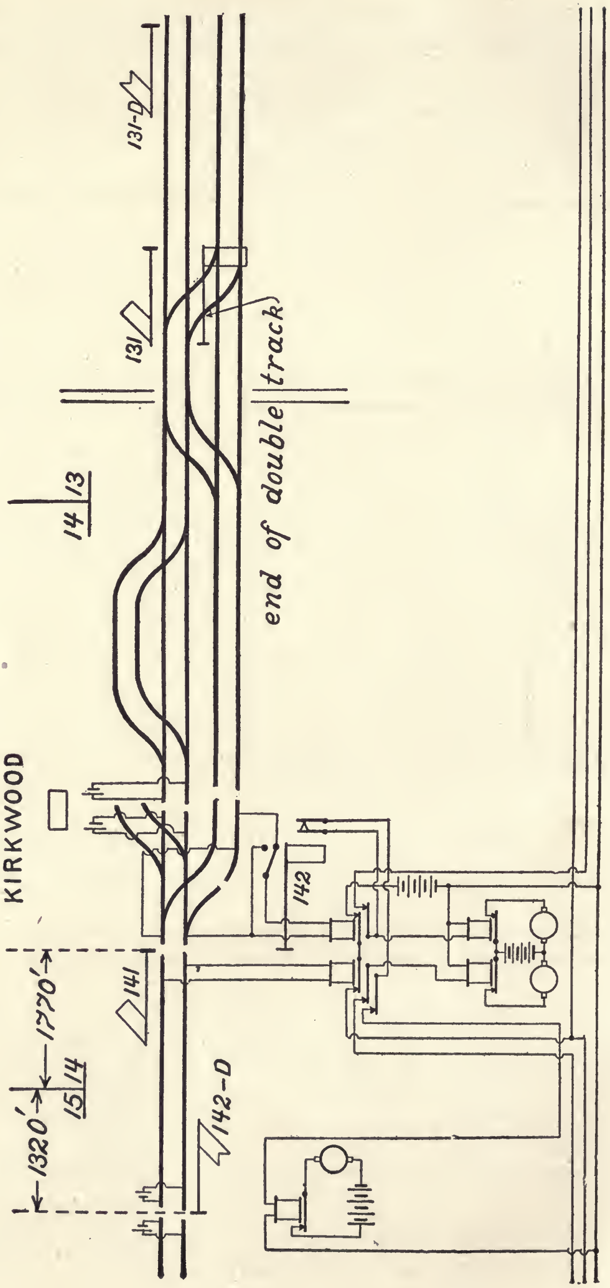

KIRKWOOD
131-D
131
14 13
end of double track
142
141
1770'
1320'
15 14
142-D

FIG. 63

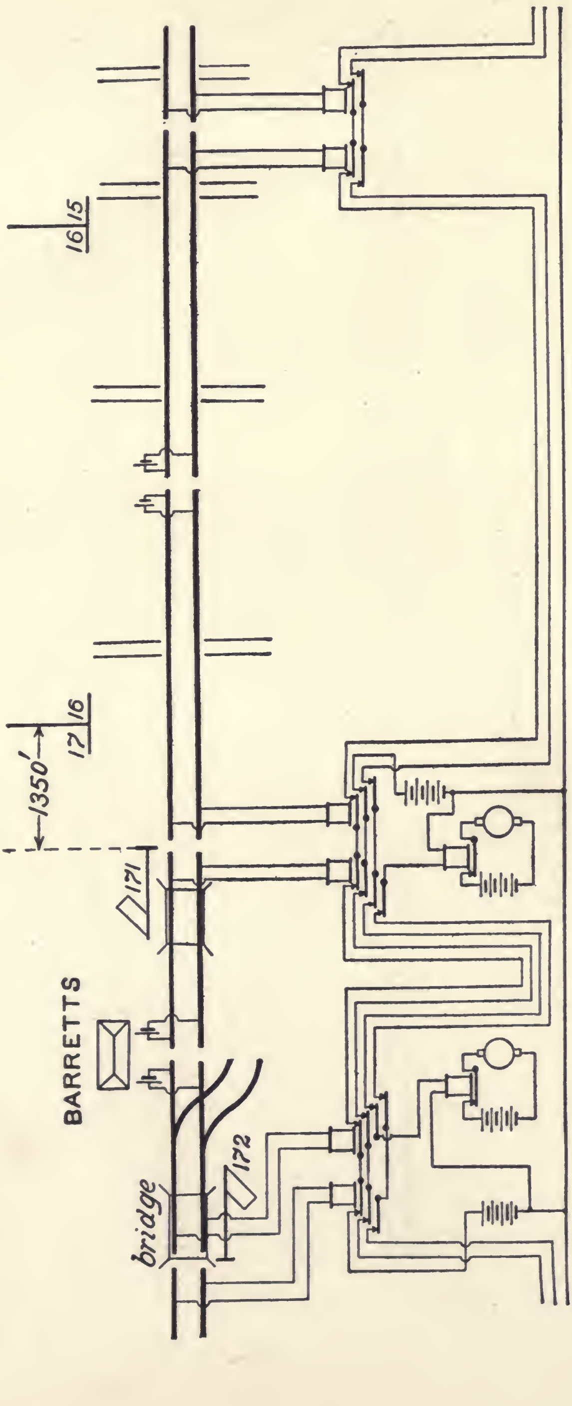


FIG. 64

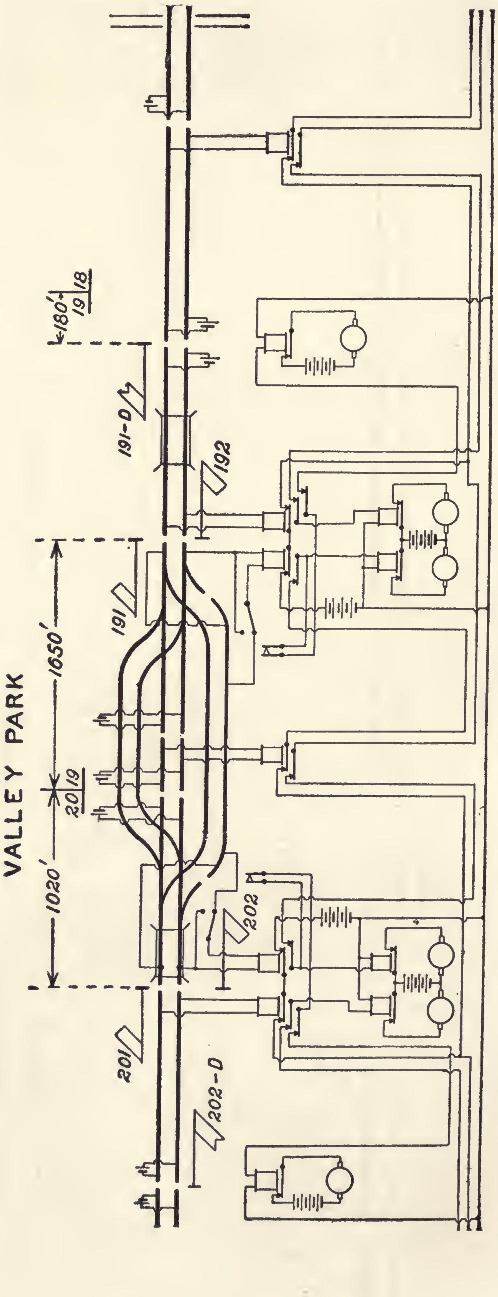


Fig. 65

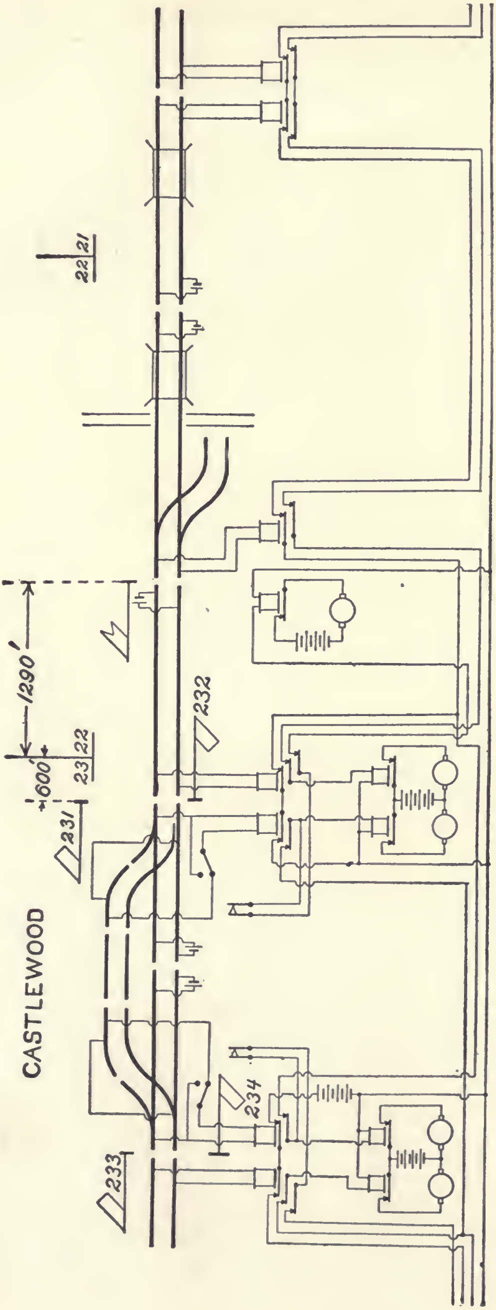


Fig. 66

The track relays at 172 and 171 have four sets of contacts each, three of these being for the line wires; thus constituting simultaneous quadruple breaks (one for each track section) in these lines, which pass to preceding and succeeding signals. At Valley Park two sidings appear, for train movement in both directions. Signals 191 and 202 each have a circuit controller and breaker, which control the track relay and section and the distant signal of each respectively. At Castlewood a single siding is introduced, the signal and connection arrangements being similar to the preceding. It will be noted that the motor batteries are not connected to the common line, since they are part of independent local working-circuits. The lengths of the various sections may be approximated from the mile posts.

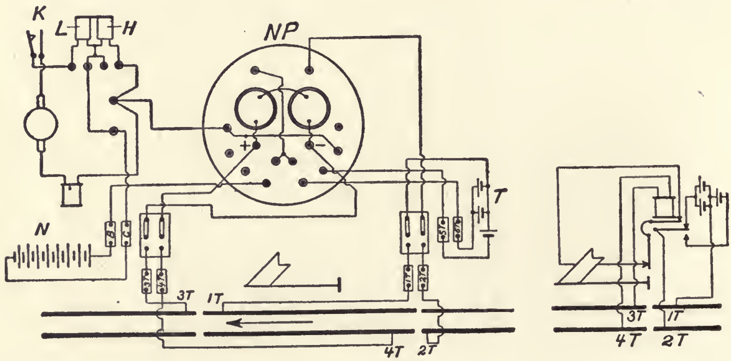


FIG. 67

The wiring for a one-arm distant in an overlap system is shown in Fig. 67,—the diagrammatic scheme of connection being represented at *A*, *NP* is a neutral and polarized relay (commonly termed simply a polarized relay). The circuit controller, *K*, operated by the semaphore, is in series with the motor and low-resistance (or compounding) winding, *L*, of the slot magnet. The high resistance winding, *H*, is connected to *N* and the front armature contacts, normally holding the signal blade at clear. The track battery, *T*, is divided into two parts, which are in series and have a common junction, 1*T*. When one of the neutral front contacts is closed, two cells in multiple are connected across the track, of a certain polarity; and when the back contact is closed, but one cell, of opposite polarity.

In Fig. 68 the connections of a normal clear home semaphore, with a separate distant in the rear, appear. The use of a slow releasing relay admits of an ordinary slot magnet, *S*, having as usual a compound winding. The track relay, *R*, has four ohms resistance, and is of the ordinary neutral type. *T* is connected to the block preceding the home signal through the polarity reverser, *P*. The armature and front point of the slow releasing relay are in series with the motor and low-resistance winding of the slot, this relay being connected across the main battery, *Q*, through the front points and armature of *R*. *N* is a circuit

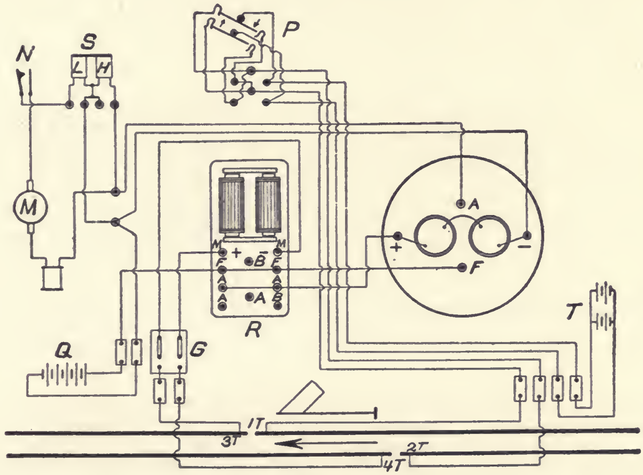


FIG. 68

breaker in series with the motor, and breaks the continuity of the working circuit when the semaphore is at full clear.

The relay and signal connections for a single-track normal clear two-arm home and distant arrangement are shown in Fig. 69. The polarity reverser, *R*, operated by the home signal, is connected to the track and track battery, *T*, thus controlling section *S* of the preceding distant semaphore circuit. The armature and front contacts, *A* and *F*, of the slow releasing relay, *K*, are in series with the home slot, *HS*, and motor, and connected to the latter through the contact springs, *A*, which, with *B* and *C*, are operated by the home blade. *D* is operated by the distant, and with *A* is normally open. Plate *G*, at the

fuse and arrester blocks, is connected to ground. The neutral and polarized track-relay has two front and two back contacts, the diagrammatic circuit-arrangement being as shown in Fig. 51.

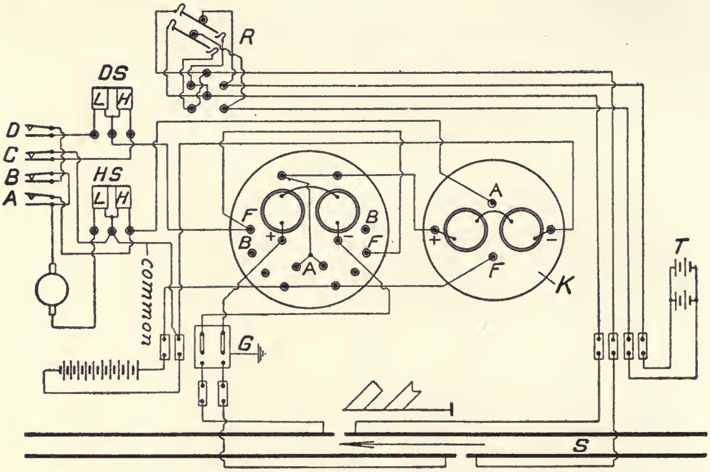


Fig. 69

A standard circuit arrangement for a normal clear wireless single-arm home signal is shown in Fig. 70. A slow releasing

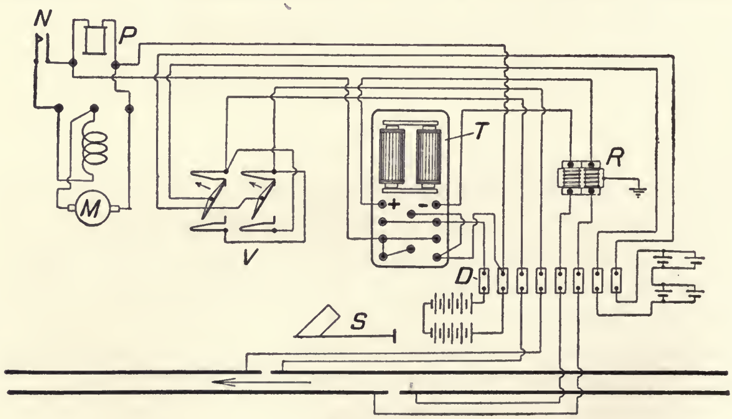


Fig. 70

slot, *P*, which eliminates a separate slow releasing relay, is connected to the common wire and the armature of the four-ohm track-relay, *T*, being in shunt with the motor, *M*. The latter

is in series with N and operates when the latter is closed, which is the case whenever the semaphore, S, is not at full clear. The polarity reverser, V, governs the distant of S through the polarized relay. In series with the magnets of T are the lightning arresters, R, the plate beneath which being connected to ground. The main binding posts and fuse strips are shown at D, to which all incoming and outgoing wires are connected.

A normal clear-wiring diagram for a one-arm home semaphore with overlaps is shown in Fig. 71. The slow releasing

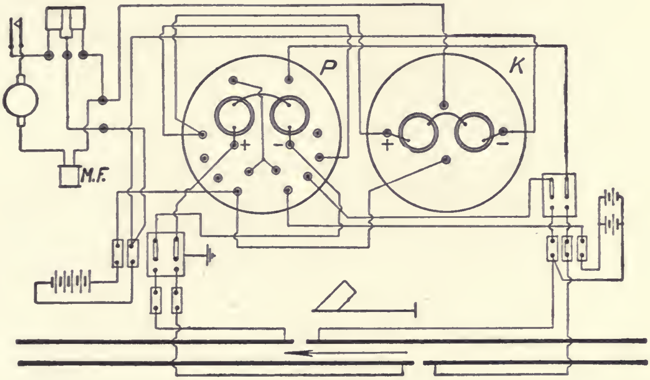


Fig. 71

relay, K, is connected as already described, but a polarity reverser is not used. Instead, the polarized relay, P, has an additional neutral back-contact and armature, which short-circuits the track upon its deënergization. In the upper or working position this armature connects the battery to the track section protected by the preceding semaphore. The scheme of connection used will be rendered clearer by the inspection of the small diagram at 71*a*.

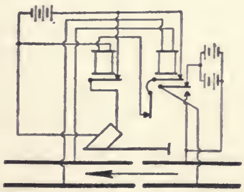


Fig. 71*a*

CHAPTER V.

SEMI-AUTOMATIC CIRCUITS.

A SEMI–AUTOMATIC signal is one having automatic appurtenances, but controlled from a manually operated signal, circuit controller, or similar devices. These are most frequently used in connection with interlocking or manual signal towers, and constitute either an adjunct or an extension of the latter. Manual signaling cannot be effected over any great length of track on either side of a cabin; hence semi-automatic distant signals have been applied to most of such cases.

An interlocking plant having mechanical fixtures with electrical control, may frequently be combined with an automatic section. Fig. 72 illustrates such a composite arrangement, with

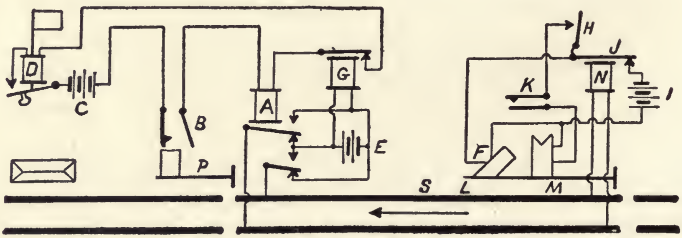


FIG. 72

a mechanical signal at danger, and a home and distant automatic signal protecting the block immediately preceding the former. *N* is a polarized track circuit relay, and *G* is a neutral relay. When the track section, *S*, is in its normal condition, and the mechanical signal is at danger, the neutral relay, *A*, is deënergized, hence its back armature contacts control the track polarity. Relay *N* receives a current of this polarity, and its neutral armature closes the circuit of the main signal battery, *I*, thus sending a current through *L* and holding it at clear.

When the home signal, *P*, is cleared, the circuit controller, *B*, is closed, which raises the armature of *D*, thus closing the circuit

of *C* and sending a current through *A*. This reverses the polarity of the track, and closes the polar contact, *H*, which throws *M* to the clear position, by sending a current from *I* through *J*, *H*, *K*, *M*, and *I*. The controller, *K*, is operated by motion of *F*, it being thus necessary for the home semaphore to clear first. The momentary cessation of current produces no effect upon the home automatic blade, because it is equipped with a slow releasing slot or magnet. This retardation of movement is produced by using in *N* a solenoid of high self-induction, wound upon copper tubes, which thus opposes any rapid change in the magnetic flux. *G* has a relatively high resistance, so that when a train enters the section, *S*, it controls, it will open the circuit of *A* and *D*. Hence the armature of *D* must be returned to its upper position when *A* has been energized, in

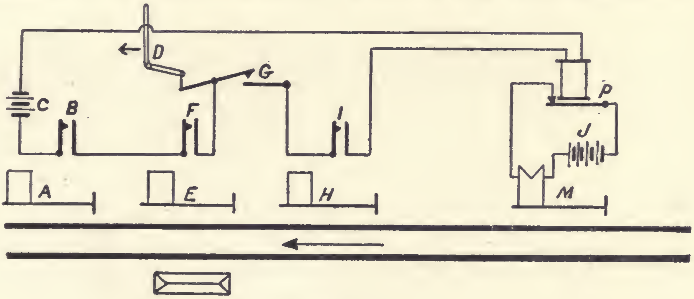


Fig. 73

order to close the circuit of *C*. Thus every train movement requires that the operator raise the armature of *D*, otherwise danger indications will be given. *F* and *M* thus operate automatically when the mechanical signal, *P*, is properly manipulated.

Frequently, a distant signal must be operated after several home signals have been cleared. For this purpose a device, erroneously termed a commutator, is placed upon each home signal in such a series. This consists merely of a make and break, similar to a controller. A series of this kind is shown in Fig. 73; *B*, *F*, and *I* are commutators, which are fastened to the masts of the home signals, *A*, *E*, and *H*, respectively. *D* is an interlocking lever, which controls through *G* the electrical functions, and is dependent on the positions of the contacts of the commutators. The local circuit, *J*, of the distant signal, *M*, is

controlled by the line relay, *P*, which is actuated by the main battery, *C*. It is evident that there may be any number of similarly connected home signals in such a system.

In Fig. 74 a circuit controller is connected mechanically to the lever, *A*, for the purpose of controlling the current from the battery, *B*, the latter having in circuit the commutator, *G*, on

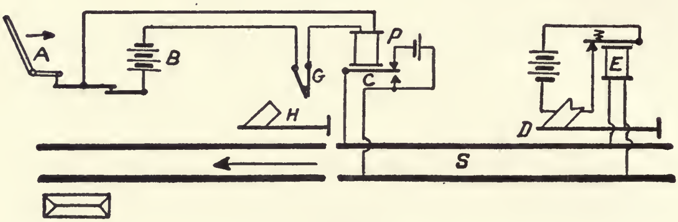


FIG. 74

the cleared mechanical home signal, *H*, and a line relay, *P*. The armature, *C*, of the latter alternately connects and disconnects the track battery at *H* from the track relay, *E*, controlling the distant signal, *D*, short-circuiting the section, *S*, in its lower or back-contact position. Current is passing through the three circuits, both signals therefore being in the clear position.

In order to shunt the contacts of a relay, so that a control outside of that produced by the energizing of the relay under operative conditions can be effected, a spring key is used. The circuit arrangement in Fig. 75 utilizes such a device. Across,

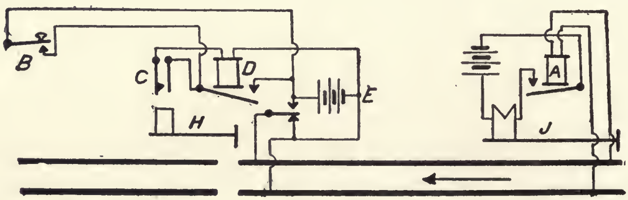


FIG. 75

or in shunt with, the upper armature of the magnetic circuit-controller and indicator, *D*, the spring key, *B*, is connected. The lower armature is connected across, and thus short-circuits the track in its lower position, and connects the track to the battery, *E*, in its upper position. *C* is a circuit controller closed by the clearing of the home signal, *H*, and is in series

with *D*. *E* energizes the track relay, *A*, at the distant signal, *J*.

When *B* is pressed downward, and *C* is closed by clearing the home signal, a current passes through *D* which lifts its armatures, the upper one maintaining the current initiated by *B*, and the lower one sending a current through *A*, thus clearing *J*.

Fig. 76 represents a scheme of connections introducing a combined indicator and magnetic circuit controller into the circuit of the line relay, *P*. This, given at *I*, consists of a solenoid, *I*, whose armature or core carries an indicating banner, *F*, to which is pivoted a lever, *G*, provided with a knob. *I* is in series with the contacts closed by movement of *G*, hence when the latter is in its lower position, current cannot pass through the circuit of the line battery, *B*.

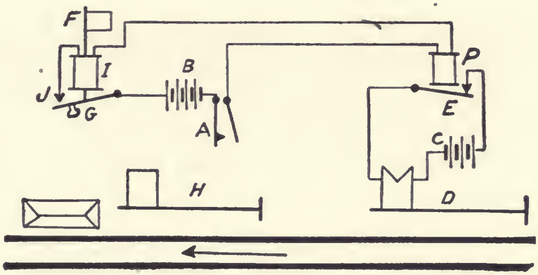


Fig. 76

When *G* is raised, the circuit is completed at *J*, and if the circuit controller, *A*, is closed, a current will pass around *I*, and, the core being energized, will maintain this condition until *A* is open-circuited. When this current flows, *D* is thrown to the clear position by current from the local battery, *C*. *A*, therefore, must be closed (by movement of the home signal) before *G* is moved; should this sequence of events not occur, *D* cannot be cleared. Since *A* is closed by the action which clears *H*, it is evidently impossible for an approaching train to pass *D*, without receiving a cautionary signal, unless a clear condition at the cabin obtains.

Somewhat similar to the above in the arrangement of accessories and circuits, is that shown in Fig. 77. In addition, a circuit controller, *P*, having a positive connection to the home

signal lever, *B*, is included. When *B* is thrown in the direction of the arrow, *H* is moved to the clear position, and the contacts at *P* closed. Unless the armature of the indicator, *A*, is raised, however, *E* will not receive current from the line battery, *C*,

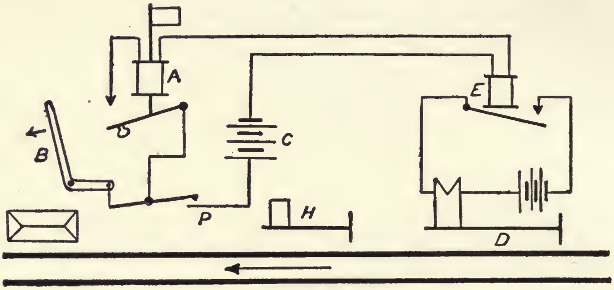


FIG. 77

hence *D* cannot be cleared. The banner on the indicator may be in the form of a miniature semaphore, or a small banner which appears before a glass-covered aperture in the case.

Adding a circuit controller, *C*, to the above, the arrangement produced in Fig. 78 is evident. This comprehends, as above

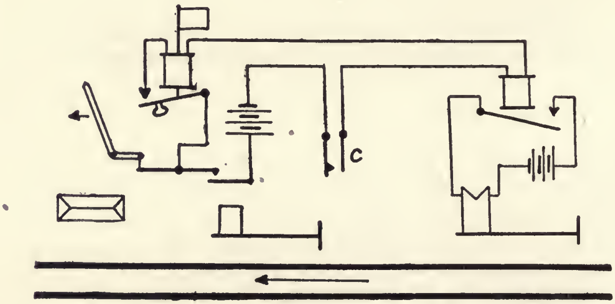


FIG. 78

stated, the addition of a protective or interlocking function, the principle of the working circuits being unchanged.

An indicator and magnetic circuit controller may have its movements automatically governed by the use of a setting track section, in which the movement of a train sets up conditions that actuate this mechanism. In Fig. 79, *D* is a short setting section having the battery, *G*, and the track relay, *F*. This

section may be of any required length, but as only a momentary initial current is required for setting this function, it usually is of but several rail lengths.

If the section, *D*, is occupied, the circuit controller, *A*, and the indicator, *C*, have no control over *E*. But should it not be occupied, then, if the operator raises the armature of *C*, with *H* at

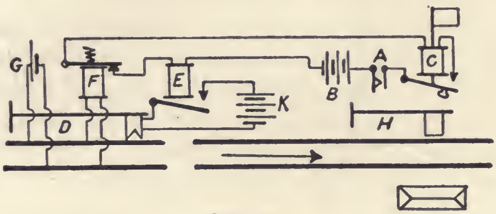


FIG. 79

the clear position, *E* will raise its armature, thus sending current from *K* to *D* and clearing the latter.

Extension of the above principle produces the circuit diagram given in Fig. 80. The lever *E* at the block tower is for the express purpose of operating the controller with which it is associated. When the home signal, *H*, is cleared, the contacts at *G* will be closed. *E* is then thrown in the direction of the

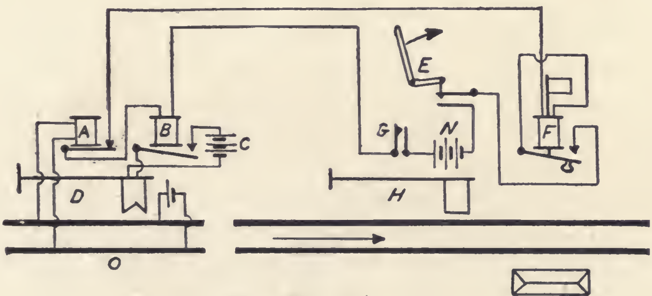


FIG. 80

arrow, which will cause a current to flow from *N* through *F* and *B*, if the setting section, *O*, is unoccupied. Should a train be in this section, however, *A* will be deënergized, and, by its armature's falling, open-circuit *N*, thus depriving *F* and *B* of current, and preventing *D* from being cleared by *C*. If the armature of *F* be restored, the same condition will obtain, since the circuit is still open at the armature of *A*.

The circuits at a representative mechanical interlocking tower, 16, are shown in Fig. 81. 15 is a charging plant from which power lines run to the various storage batteries. At the east-bound signal, 6, the track polarity is under the control of the arrangement, 4, the operating magnet being in series with the contacts, 5 (closed when 6 is clear), two of the controller contacts, 10, battery 8, and the cable. Signal 6 is operated by battery 18, through line 23 and armature of 25, and signal 1 (at clear) by battery 3, through the polar contacts of the polarized relay, 2. The latter receives current from a track cell and reverser in the rear, while 24 energizes 20. Relay 21 operates a reverser connected to a section preceding 14, the latter receiving current from 3 through the interlocking tower.

A circuit controller, 17, is opened when the signal, 26, is at danger, and is in series with the next signal in the rear. A track relay, 22, is connected to the crossing track, 27, its armature contact being in series with the front contacts of 20 and 28. The series electric locks, 7, applied to mechanical levers, are connected to battery 8 through lines 29 and 31 and common line 30. Controller 13, operated by 14, is in series with controllers 10, contacts 5, relay 4, and 21. Considering the circuits already described, no difficulty should be encountered in comprehending the entire arrangement. It is evident in the above circuit diagrams that a common main battery may be used for numerous functions. In practice a single battery is often employed to furnish current for a multiplicity of such receptive devices, and sometimes to energize an entire circuit network of great complexity.

The normal clear circuits at the Newark drawbridge of the D. L. & W. over the Passaic River are shown in Figs. 82 to 87. The plans are consecutive from *A* to *J*, lines and other circuit wires being numbered to render easy tracing up possible. No. 7 is the common line and its connections, and is shown heavy.

In Fig. 82 signals *M* 81 are for west-bound movements, and *M* 82 for east bound, all four being placed upon a signal bridge. Relays marked *NP* are both neutral and polarized, while those marked *H* are neutral only, and have resistances of four ohms. The distant blades at *M* 82 are semi-automatic, 40 being controlled by the armature contacts of the 500-ohm slow releasing relay 42, through the circuit breaker, 43 (operated by the home

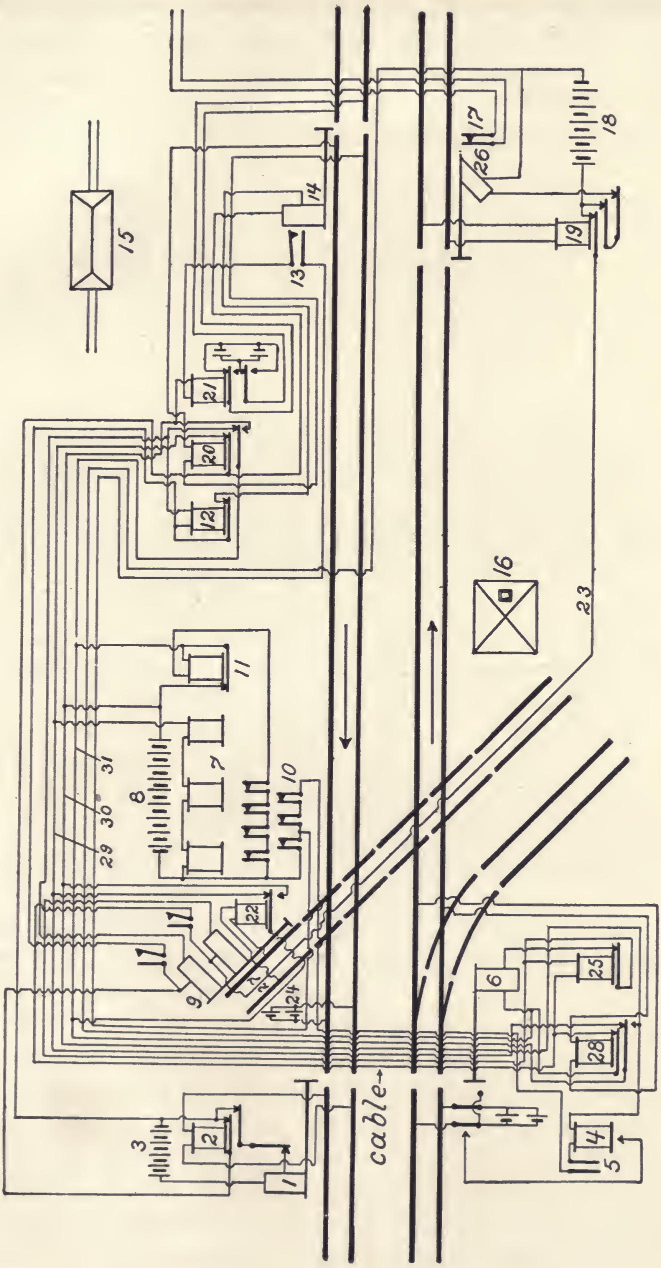


FIG. 81

blade), the line 28, and east-bound hand switch, *E*, at the mechanical interlocking tower of Fig. 84. The home blade, 44, operates two circuit breakers, 45 and 46, they being connected in series with the distant and line 32, the latter passing to the middle east-bound distant at the next bridge west. Line No. 35

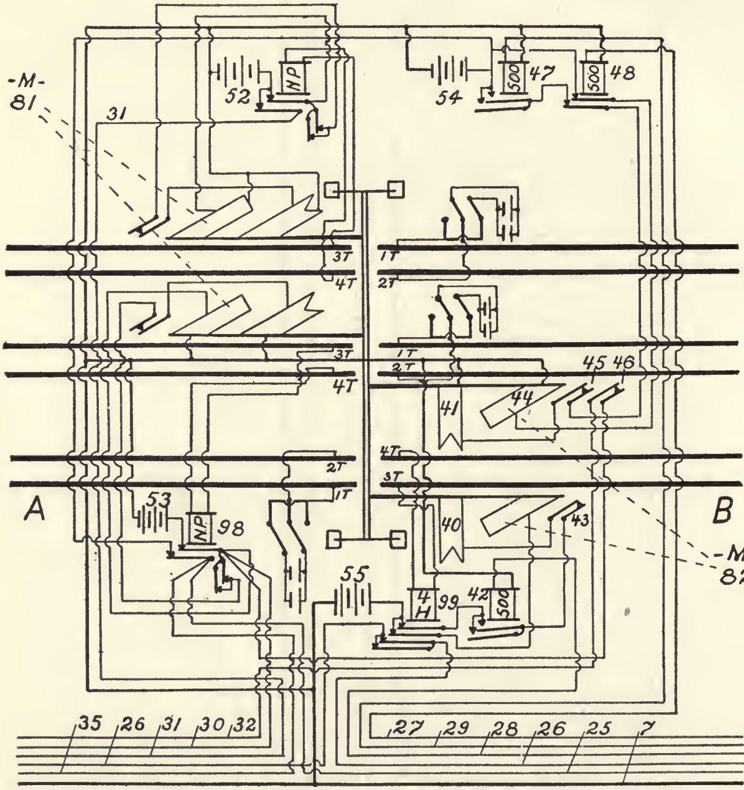


Fig. 82

passes to the west-bound middle track distant indicator for Roseville Avenue, No. 26 to the east-bound distant indicator, No. 31 to the west-bound (outside track) distant indicator for Roseville Avenue, No. 30 to the operating mechanism of the middle east-bound home signal at the next bridge west, No. 32 in series with the operating devices at the distant of the same signal, and *A*–50 to the transmitter, *T*, at Fig. 84.

The 500-ohm slow releasing relay 47 is energized through lines 29, the circuit breaker 49 at mechanical signal 16 of Fig. 83, the middle east-bound hand switch, *M.E.*, at *E–F*, and batteries 50; returning through the common, to which all working batteries and most of the other accessories have one side connected. Its armatures are in series with 41 through 45. Relay 48 is controlled from the armature of 51 at *C–D* through line 27, and controls, through its armature, both 41 and 44. The signal batteries 52–53–54–55 operate the signal mechanisms

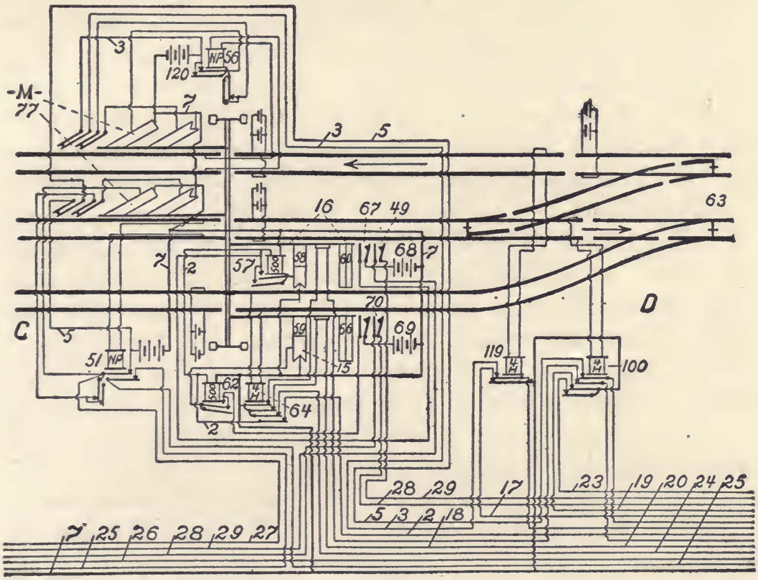


Fig. 83

they are adjacent to, the polarity reversers being operated by the home blades of these signals.

In Fig. 83 the west-bound signals, *M* 77, are purely automatic, and controlled by the polarized track-relay 56; while 15 and 16 are semi-automatic, and under the control of electric slots in series with lines 18 and 20. Relays 57 and 62 are in multiple, and connected to common and line 2, in series with the lower armature or front contact of east-bound track-relay 64. Line 2 runs to the circuit breaker 82 of 1 *D* at *E–F*, and the track-relay contact 86 at this point; the slow releasing relay 57 controlling

the distant arm 58 through the circuit breaker 67; 60 and 66 being thrown by levers; 59 is controlled by 62, and is clear whenever 58 is, since 62 and 57 are in multiple.

At 63 a switch merges the east-bound and middle tracks, thus removing the necessity for four-movement indication. 68 is the independent local battery for 58, and 69 for 59. Neutral track relays, 100 and 119, produce the required track circuit and line-wire control. Although it is possible to use a smaller number of batteries, line wires, relays, etc., in such a complicated situation and produce the same results, crossing of circuit wires would set up conditions that would entail considerable vexation in eradicating, while, by the use of as many independent circuits as is consistent with economy, such troubles seldom occur, and are more readily traced. The use of common wires has often led to troublesome conditions, but such is usually the result of poor insulation and careless installation or maintenance.

In Fig. 84 the circuits at the mechanical interlocking tower are given. *E*, *M.E.*, *W*, and *M.W.* are the east, middle east, west, and middle west-bound control line switches. One side of each of the east switches is connected to the common battery wire, *B*, and the multiple batteries at 50, the other sides being connected to lines 28 and 29, in series with circuit breakers 49 and 70, and through additional circuits already traced. An intercommunicating telephone instrument, 71, is in circuit with 72 at the drawbridge (*G–H*) so that communication can be carried on between these points. 73 to 79 are indicators, 73, 74, 75, and 79 having contact armatures, the energization of the magnets thus clearing not only their banners but raising also these armatures. A sixty-ohm bell, 80, is closed by a back contact of either 73 or 74, 81 being energized through the back contact on 79.

73 receives current from battery 54, through line 25, and the front neutral contact of polarized track relay 98 at *A–B*, and is the middle east-bound indicator; 75 is the east-bound home through battery 50, line 24, contact of relay 64, and common; 76 the east-bound advance by way of line 22, contact of 86, and common; 77 the middle home through line 23 front contact of 100, and common; 78 the west-bound home by line 21, front contact of 90, and common; 79 the west-bound distant

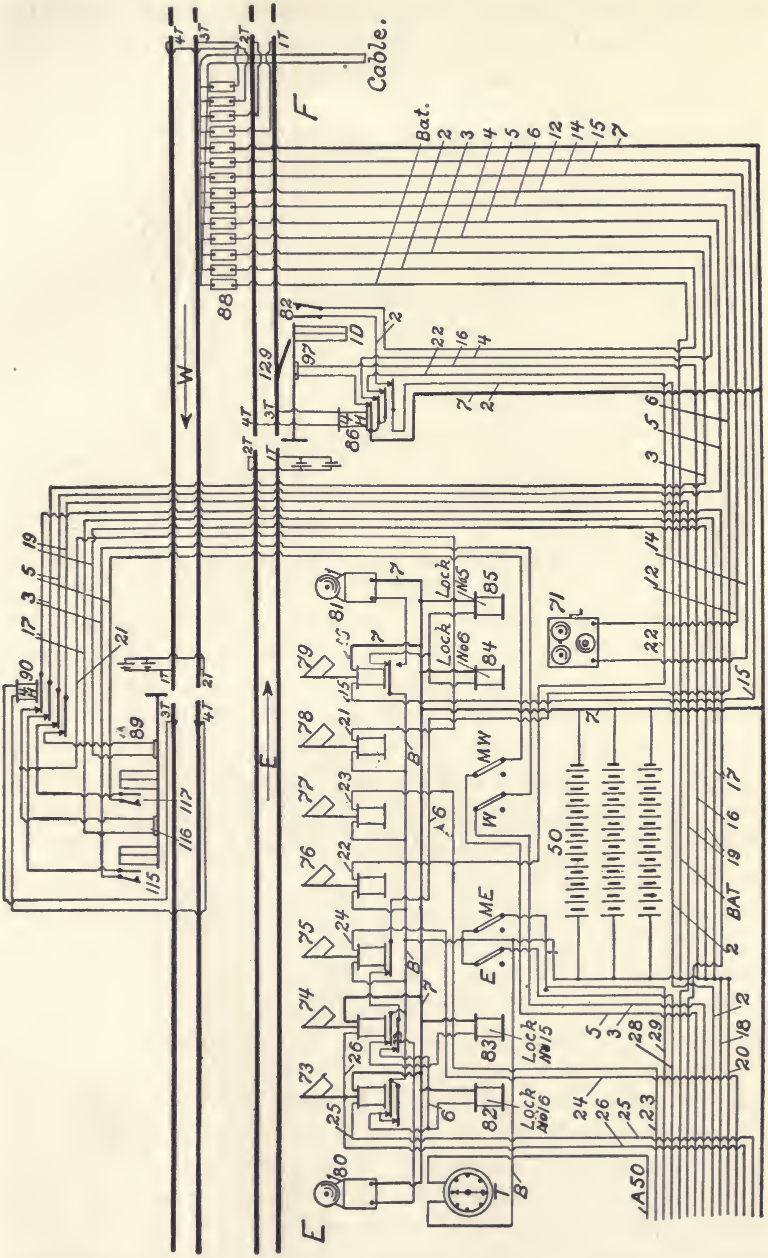

Cable.
Bat.
F
W
E
88
Lock No 5
Lock No 6
Lock No 15
Lock No 16
MW
ME
BAT
A50

Fig. 84

by line 15, contact 15, cable, west-bound home indicator contact of 101, to battery by the front contact of 106.

82 is the lock magnet on mechanical lever No. 16, which operates the home semaphore, 16, at *C–D*, and is energized from 50 through the front contacts of 73 and 74 in multiple; that is, it releases the lever whenever either its east-bound middle or east-bound distant is cleared; 83 is the lock for lever 15, or east-bound outside semaphore at *C–D*; 84 for No. 6 at 116; and 85 for No. 5 at 116. Unless 90 is energized the semaphores at 117 will be in the stop position, because of the slots, 89 and 116, which are thus controlled by a track circuit. Circuit breaker 115 is in series with line 3 and one front contact of 90, also one contact of 119, circuit breaker at *M*–77, battery 120 and common, and on the other side through line 3, and connector 3 at 88, and cable. 117 is in series with one of the front contacts of 90, line 5, 5 at 88, cable, circuit breaker 126 at *IJ*, 500-ohm relay 130, and common. A slot, 97, also controls 1 *D* (at which a derail appears) through 86, line 16 and battery *B*. Subsidiary devices do not enter in this case, as the track circuit at the approach and over the draw perform all the necessary functions. The cable is carried to the center of the draw, the track circuit connections being made so that the track forming part of the draw is electrically continuous with that at the abutments. The circuit breaker, 82, is in series with line 2, front contact of 86, common, 2 at 64, east-bound hand-control switch 113, connector 2, cable, circuit breaker 122 at *M*–74 (*I–J*), battery 121, and common. At 127 there is a derail, as also at 129.

Continuing on Fig. 85 (*G–H*), the bridge controller lock, 112, is in series with a circuit breaker on lever No. 5, which is open when the bridge is locked, so that when the former is energized, the bridge is not in its safe position. A single-stroke bell, 107, is connected to the armature contact of approach indicator 105, so that when the latter has a current passed through its coils, the gong will be struck once, this occurring through line 37, whose connections will be shown later. 109 receives battery current through the back contact of the west-bound distant indicator, 106, and 108 through the same contact of the east-bound distant indicator, 102. The bridge indicator, 104, is in series with the wire 36 and the signal battery at 9 *D*, through the cables;

103 is the east-bound home indicator connected to battery 50 and line 4; the circuit being completed through one of the front contacts of 86 and common. The lock magnet, 111, is connected

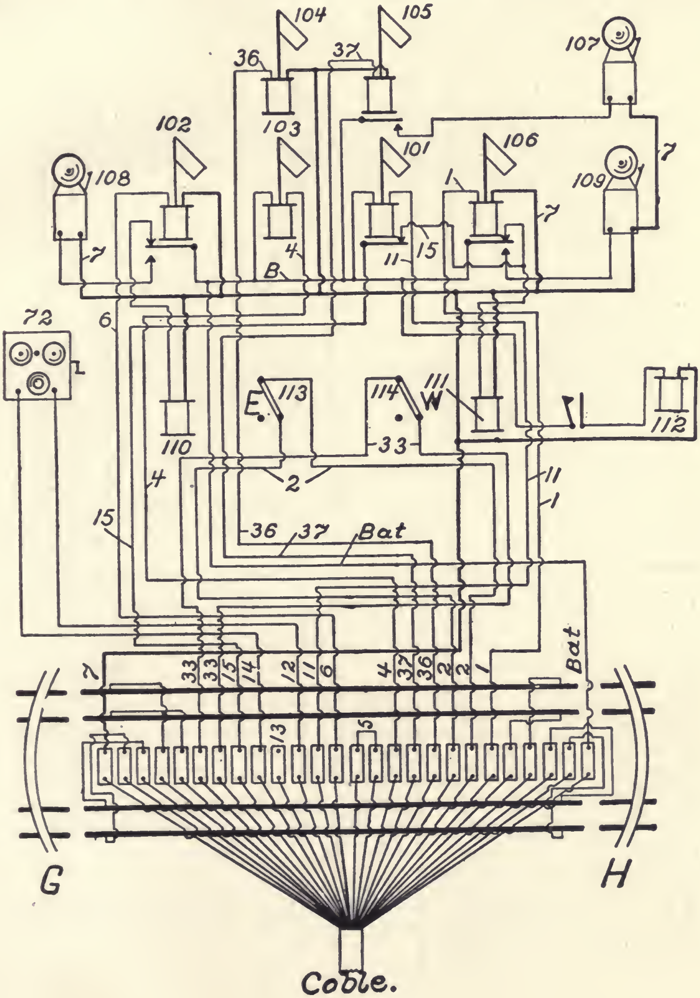


Fig. 85

to lever 9 of that signal, and is in series with the front contact of 106. The west-bound distant indicator 106 is connected by line 1 to the cable, one contact armature of 135, and to the west-

bound home indicator at Harrison, the next signal point east line 11 E, operating the west-bound distant signal at this point.

In Fig. 86 (I–J) the east end of the cable and connections

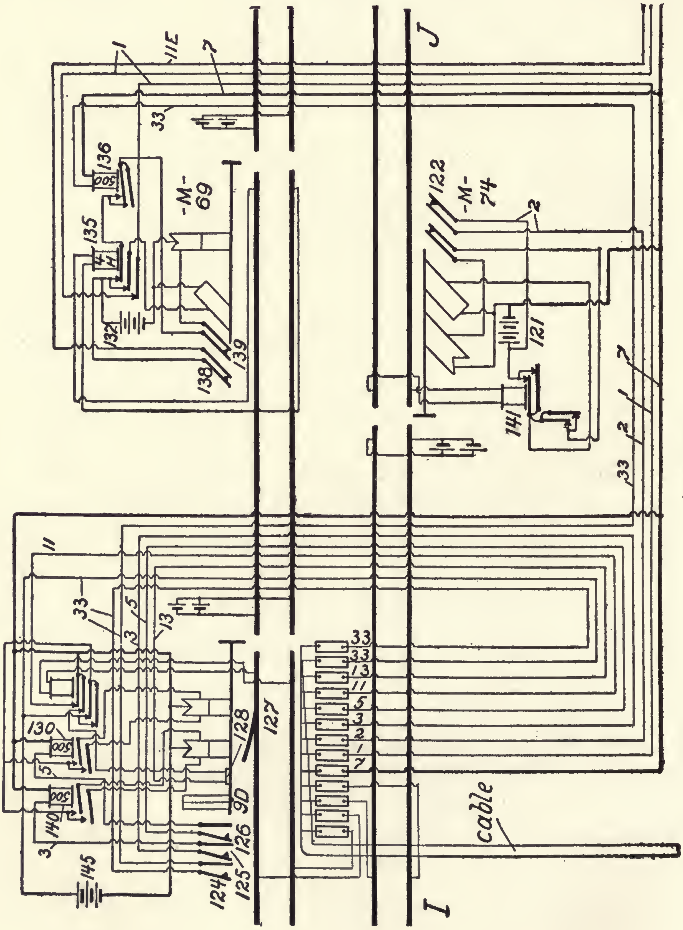


Fig. 86

are shown with the mechanical semaphore, 9 D, and the automatic signals, M–74 and M–69. The four-ohm track relay, 135, controls east-bound signal M–69, 137 being the working battery. A high-resistance slow-releasing magnet, 136, is in series with line

33, circuit breaker 124, cable, west hand-switch 114, and battery 145; while a similar magnet 130 is in series with the circuit breaker, 126, and line 5 (all three circuit breakers are closed when 9 *D* is cleared). 9 *D* is also under the control of slot 128, which is energized through the track relay contacts. Circuit breaker 125 controls 140, and 138 the preceding distant sema-

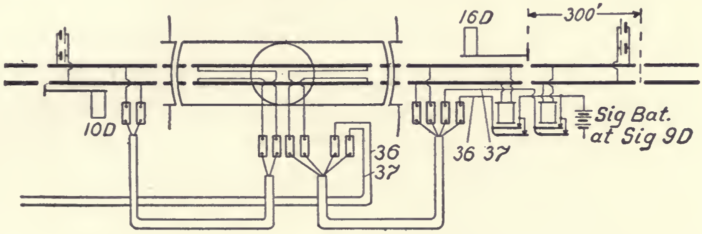


Fig. 87

phore, while 139 is in series with the distant at *M*–69. A polarized relay, 141, is used at *M*–74, battery 121 operating both home and distant semaphores.

The track circuit and other connections at the lower deck of the draw appear in Fig. 87, with two manual signals, 9 *D* and 10 *D*. With the foregoing description in view, it need not be dissected.

CHAPTER VI.

BATTERIES.

The primary cells most generally used in signal installations are the following: (1) Gravity; (2) Gordon; (3) Edison. All are of the closed-circuit type; that is, they are capable of withstanding continuous full normal-current discharge.

Open-circuit cells are but little used; for, while certain work is intermittent in character, it has been found that cells of this type are not to be depended upon. For ringing electric bells at places where inoperation will not result in serious consequences, the Leclanche or sal-ammoniac cell has been applied with restrictions.

In the gravity cell, which is of the two-fluid type, the different specific gravities of the liquids used is the only principle involved in keeping them apart; porous cups and diaphragms being thereby eliminated. These liquids are a saturated solution of copper sulphate and a dilute solution of zinc sulphate and sulphuric acid, the latter being formed only during the action of the cell, which is shown in Fig. 88. The copper element, *C*, rests upon the bottom of the containing jar, and is connected to the external circuit by an insulated wire. The copper is partly covered with crystals of blue stone or copper sulphate (CuSO), these crystals being surrounded by a strong solution of copper sulphate. Above this latter solution, and distinctly separate from it, is the solution of zinc sulphate, in which the zinc, *Z* (a common type of which is shown also at *D*), is immersed. This zinc is supported by the bent bare copper wires, *G*, which are cast in the former. The action of the cell is as follows:

When the external circuit is closed, the small amount of sulphuric acid (or water if the former is not present) attacks the zinc, forming zinc sulphate and hydrogen. The zinc sulphate remains in the upper part of the liquid, while the hydrogen passes to the copper sulphate, and thus forms sulphuric acid

and metallic copper. The copper is deposited upon the copper element, while the sulphuric acid rises and attacks the zinc, this cycle being repeated as long as the external circuit is closed.

These reactions are expressed as follows: —

$$Zn + H_2SO_4 = ZnSO_4 + 2H.$$
$$2H + CuSO_4 = H_2SO_4 + Cu.$$

When the water of the solution is decomposed, oxygen is liberated. The copper which is deposited upon the copper element must be loosened each time the cell is renewed, or the accumulations

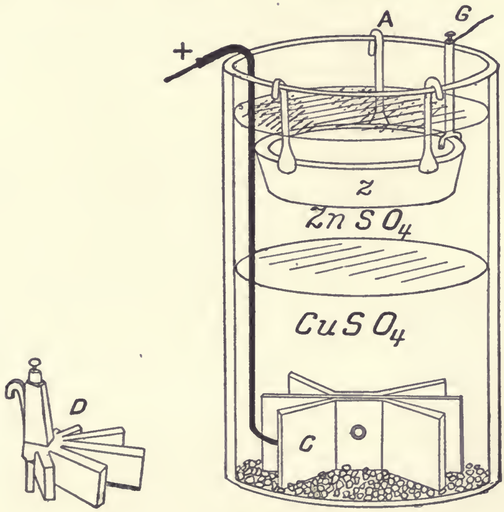


Fig. 88

will become too solid for removal. When a gravity cell is in proper condition, the blue line of separation should be midway between the two electrodes.

The e.m.f. of this cell on open circuit is 1.07 volts; and the internal resistance from about .5 to 3 ohms. This will give a current on short circuit of from .3 to 2.5 amperes. The cell is most commonly used for track circuits on account of its perfect electrochemical depolarization. To a certain limit of saturation of the upper or zinc sulphate solution, the greater the continued demand the more satisfactory the operation. A disadvantage of the cell, however, is the high internal resistance.

The loss this entails depends upon the resistance of the circuit to which it is connected; since this loss (C^2R) depends upon the relation of the internal resistance to the total resistance.

The internal resistance of a gravity cell being 0.5 ohm, the maximum $\frac{c^2}{v}$ factor that can safely be allowed is 2, which at .30 gives an economic power valuation of 2.2.

In the Gordon cell, the elements are iron and zinc, while the exciting liquid is a strong solution of sodium hydrate or caustic soda, NaOH. The containing jar is either glass, porcelain, or enameled steel, depending upon the conditions to be met. Steel and porcelain have a longer life, and are much less liable to failure during recharging and operation than glass, but the operation of the cell is not visible, as is desirable to determine the point when renewal must be accomplished.

Fig. 89 illustrates a 300-ampere-hour cell, such as is most frequently used for signal and grade-crossing circuits, the jar being 6 in. by 8 in. in size. *Z* is the positive zinc element, which is a sheet bent to a cylindrical form; it being of about one-eighth of an inch in thickness. This is thoroughly amalgamated, to prevent local action, and is supported on three porcelain lugs, *P*, fastened to the perforated cylinder, *D*, which it surrounds. This latter is partly filled with a flaky oxide of copper (CuO), the iron and this compound forming the negative element. Contact is made to *D* by a binding post or connector, the threaded connection to which is screwed into a nut in the top of the cylinder. The sheet iron cover, *C*, supports *D* and Z by the binding action of two porcelain washers, *A*, one above and the other below *C*. The zinc is connected to the external circuit by the insulated wire, *W*, which is riveted to the former and further insulated from *C* by a small porcelain bushing. The riveted connection is covered with asphaltum to prevent local action at the junction of the copper and zinc.

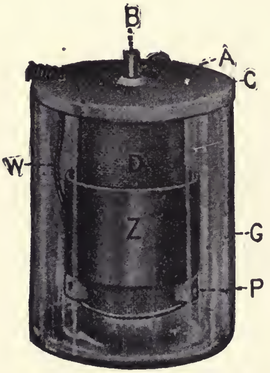


Fig. 89

When the cell is renewed, the entire cylinder and contents, also the remaining zinc, is thrown in a scrap pile. Formerly,

the exhausted copper oxide was removed and replaced, the entire arrangement being dismantled to do this; resulting in much labor and, without care, painful sores on the hands of the batteryman. Thus one of the objectionable features of the sodium hydrate cell has been removed.

An exciting solution of from 20 to 25 per cent is employed; in other words, three or four pounds of water to one pound of pure caustic soda. The copper oxide and zinc are so proportioned that all the elements are exhausted at once. A heavy mineral oil is used to cover the surface of the exciting solution, as this latter has a strong affinity for the CO_2 of the atmosphere, which if not otherwise prevented would result in rapid deterioration of the cell. The reaction is shown in the formula:

$$2NaOH + CO_2 = Na_2CO_3 + H_2O.$$

The sodium carbonate (Na_2CO_3) thus formed is not only of little value in setting up an e.m.f., but it also is of a creeping character, crystalization taking place over the edges of the jar and cover, resulting in rapid destruction of the latter.

During the action of the cell, sodium zincate is formed as follows:

$$2NaOH + Zn = Na_2ZnO_2 + 2H_2.$$

The hydrogen passes to the copper oxide and forms water and metallic copper, thus:

$$2H + CuO = Cu + H_2O.$$

The Edison cell is also of the single-fluid type, and now employs an exciting solution of caustic soda or sodium hydrate, NaOH. In its action it is somewhat similar to the Gordon, but of a different mechanical construction. Formerly, caustic potash solution was used, but as this is even more difficult to handle than the sodium compound, it has been abandoned. Fig. 90 shows the cell in part section. A cover, *B*, of porcelain, has a recess which fits into the top of the containing jar. In the center of this cover there is a boss, on each side of which stems or lugs, *L*, incorporated with the zinc plates, *Z*, are securely clamped by the thumbscrew connector, *C*. Within a slotted frame of copper, *F*, are placed two porous, compressed, and beveled plates of cupric oxide, *O*, with surfaces reduced to the

metallic state for increased conductivity. These plates have a binder of magnesic chloride, and are secured in place by the copper thumb bolts, *N*. Two insulating tubes of hard rubber, *T*, are placed on part of the frame which emerges from the liquid, and prevent the current from leaking across the surface of the liquid to parts of opposite polarity, also protecting the frame from corrosion at the junction of the oil and solution. The liquid is covered as before with a heavy mineral oil, and the external circuit wires are fastened to the connectors, *A* and *C*.

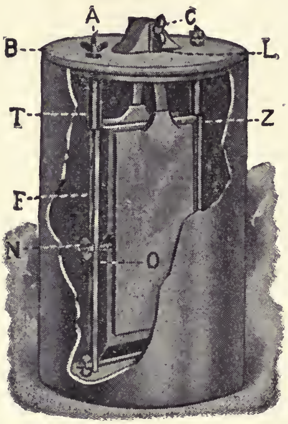


Fig. 90

The cell is renewed by removing the zincs, oxide plates, and solution, and replacing by new elements, care being taken to have all nuts and connections tight. The entire old solution is thrown away and the new liquid substituted, a fresh bottle of oil being poured over the surface. Before replacing the new elements, they should be dipped in clean water, to prevent the oil, which is of high viscosity, from adhering when they are immersed in the solution.

The water used in renewing all cells should be taken from a running stream or hydrant, as stagnant water contains vegetable and animal impurities which render it unfit for battery purposes. For this reason it is not practicable to locate barrels filled with water near the battery chutes, as animalculæ soon manifest themselves. Spring water is not always valuable, as it may contain mineral substances whose reaction is deleterious to the proper action of the cell. When mixing caustic soda solution, the soda should be slowly poured into the water, and the latter rapidly stirred at the same time, as failure to do this will result in its falling to the bottom and solidifying. Should any of the solution get on the hands or face it may be readily eliminated by applying a vegetable or animal oil or grease, which is thus converted into soap. If glass jars are used, they should be placed on dry wood or ties, to prevent cracking at the bottom, owing to unequal expansion.

The surface of the liquid should be about one inch above the top of the zinc and oxide plates, for if the latter project above the liquid, the bare parts will be rapidly destroyed. Also fine particles of metallic copper may fall from the oxide plates and by floating upon the plane of separation of the oil and solution, ultimately short-circuit the cell. The condition of the oxide plates may be ascertained by picking into them with a sharp knife. Should they be copper colored throughout, they are exhausted; but if the central portion is black, they are still of use, the continuity of life depending upon the relative thickness of this inner black layer. Using an exhausted set of plates results in rapid depolarization, while it is not advisable to use plates that have been left in the air and consequently partially reoxidized, as this natural oxidization occurs only superficially.

A 300-ampere-hour capacity has an internal resistance of .025 ohm, a working voltage of .667, a continuous-current delivery of 6 amperes, a short-circuit current of 26.7 amperes; consequently a $\frac{c^2}{v}$ factor of 17.78, and a $\frac{c^2}{pr}$ factor of 5.34, when $p = .30$. The low internal resistance is advantageous when the cell is called upon to deliver heavy currents; that is, when connected to a low external resistance. The ratio of the energy lost in the cell to the total energy expended is then very low.

The disadvantages of the sodium hydrate cells are the caustic nature of the exciting liquid, the low terminal voltage, the rapidity with which they give out, and the excessive heat caused by the dissolving of caustic soda in water. The indication that a cell needs renewing is the segregation of crystals of sodium zincate upon the zinc element, a condition occurring without much warning. The use of oil on the surface of a liquid is also rather troublesome, as the inside surface of the jars must be frequently cleaned. Also a large percentage of the cost of operation is in scrap which is not really utilized.

The advantages are the uniformity of operation, freedom from local action, low internal resistance, constancy of current output, ability to withstand low temperatures, the absence of noxious or combustible vapors, and the adaptability for heavy current output.

Storage cells have many advantages over primary cells which make them particularly adaptable to certain phases of signaling.

Where large amounts of energy are required, and it is not advisable to install a separate generating plant, storage cells may be economically applied, being charged by a portable generating set. Such an arrangement has the advantage of a large and steady output, with a smaller number of cells than the closed-circuit primary cells we have considered can have. The average e.m.f. of a storage cell is 2 volts, so that three Edison cells can be replaced by one storage cell, as far as voltage is concerned. When a stationary generating set is used, the signal batteries are charged through the aid of line wires which run from the plant and include the cells in series.

Most of the accumulators used in signal practice have positive and negative plates of lead and an electrolyte of dilute sulphuric acid (four parts of water by volume to one part of acid, giving a specific gravity of 1.2). The lead plates are "formed" mechanically or electrically, and are fastened together in substantial shape.

Storage cells are rated according to the number of ampere-hours they are capable of discharging until the terminal e.m.f. of a cell falls to 1.8 volts, the e.m.f. when fully charged being 2 volts. However, since sulphating sets in below 1.9 volts, they should never be discharged until the e.m.f. becomes less than this figure.

A 300-ampere-hour cell may be charged at a normal current of 30 amperes, the charging continuing for 10 hours; which also represents the normal rate of discharge. Smaller capacities require less current; a 50-ampere-hour cell taking 5 amperes under normal conditions. It is better practice to prolong the charging time by decreasing the current. Better results are also obtained when discharging at a low rate, a 150-ampere-hour cell being capable of delivering 190 ampere-hours with 38 hours allowed for both charge and discharge, and only 120 ampere-hours at 5 hour discharge rate.

When charging, the e.m.f. of the generator should be 10 per cent greater than the total e.m.f. of the cells when charged. The resistance of a cell is very low (.003 ohm for an average 300 ampere-hour cell), hence it is necessary to include a resistance of some kind in series when charging. To illustrate, suppose 40 such cells were connected in series on a 110-volt circuit. The cell e.m.f. which will oppose that of the supply circuit would be

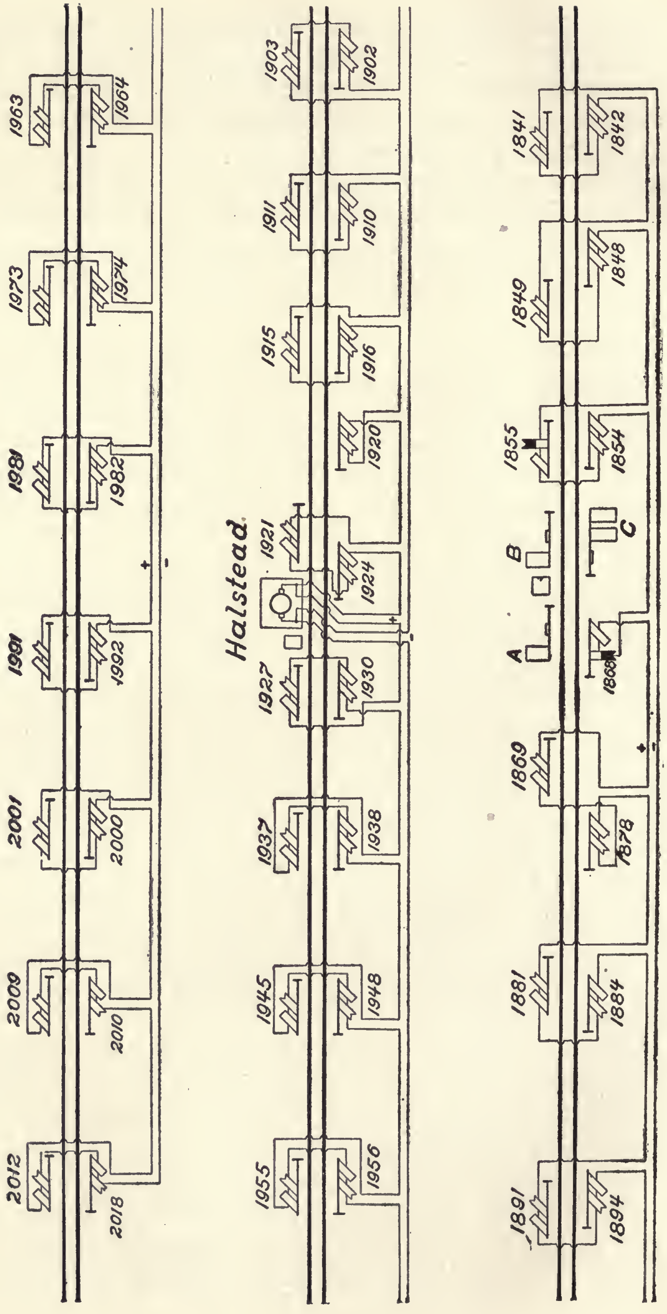
40×1.9, or 76 volts. Then $110 - 76 = 34$ volts; resulting in a flow of $34 \div (40 \times .003) = 283.3$ amperes, which of course is an excessive current. With a resistance of one ohm in series, on the other hand, the current would be $34 \div 1.12$, or 30.3 amperes, which is a normal value.

Usually the line has sufficient resistance to prevent an excessive current flow; but in any event it requires careful calculation. It is advantageous to have a small variable resistance (rheostat) in circuit so that the charging current may be adjusted to the required value.

Accumulators should be installed in a dry place, having an average temperature of about 70° F. Charging may be continued until gasing sets in, a phenomenon caused by the liberation of hydrogen, which gives the electrolyte a boiling appearance. High insulation must be maintained; otherwise the leakage factor will be high, and trouble encountered with foreign currents in the track circuits.

Storage batteries may be charged from commercial power circuits, or through the medium of a portable generating plant. In the latter case, gasoline engines are preferable, the generator being direct driven, except in the case of small units. If alternating current is available, it is converted to direct at the proper voltage by a motor generator or mercury rectifier. In all-electric interlocking 110 volts is the standard pressure; 55 storage cells being connected in series to obtain this e.m.f. The capacity of the individual cells depends upon the work they perform in a given time, usually 24 hours, the cells being charged so often. With such installations, a switchboard is necessary. Such a board should contain an ammeter, voltmeter, pilot lamps for indicating grounds, circuit switches, charging rheostat, fuses, and circuit breakers (both overload and reverse current).

A mercury converter or rectifier is now used for charging storage signal-batteries from alternating-current mains. This device suppresses the negative wave of the alternating side and converts it into a pulsating direct current, with intervals of partial current cessation. Such a current can readily be employed for charging purposes, although it could not be used directly on the signal motors or relays, due to the resistance offered by such inductive devices; with consequent heating and loss of


Halstead
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1948
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1841
1842
1849
1848
1855
1854
A
B
C
1868
1869
1878
1881
1884
1891
1894

Fig. 91

energy from eddy currents and inconstancy of the available e.m.f.

Mercury rectifiers should be mounted upon a switchboard, containing the main switches and connections, with a transformer, having a variable secondary voltage. The charging wires run either to separate portable battery sets, or to the charging line. This arrangement is not only economical, but

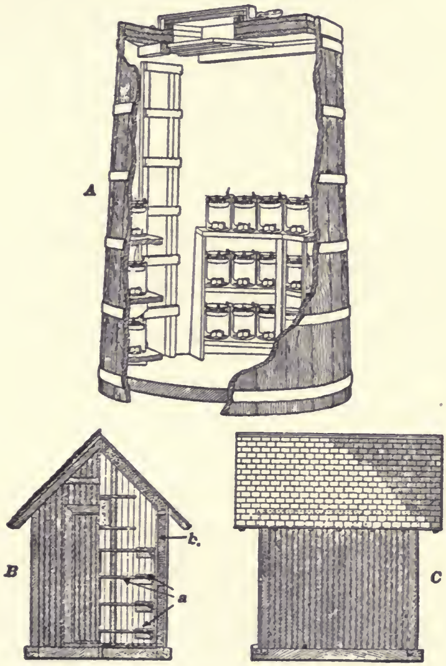


FIG. 92

practicable; and transmission may be effected over great distances, and from isolated points, at any primary potential.

Fig. 91 is the plan of a charging arrangement used on the D. L. & W. is shown. The charging plant is located at Halstead, N. Y. (192.5 miles from New York City), the total territory covered being 17.7 miles. Forty-four two-arm signal mains are charged in this fashion; *A*, *B*, and *C* being slotted mechanical signals.

While nearly all forms of primary batteries used in signal

practice are of the non-freezing types, it is advisable to make battery shelters or houses as impervious to cold as possible. The internal resistance of cells increases with decrease of temperature, and when the surrounding air has a temperature below that of freezing, the action is sluggish, the current discharge being low and the requisite circulation of the exciting liquid poor. In Fig. 92, *A* is a wooden battery tank or well which may conveniently be installed below ground, with the top projecting above the surface. The latter is weatherproof and provided with a hinged cover, while the cells are arranged in tiers, upon ventilated shelves, for ease of inspection and renewing. The inner base is provided with drainage holes, the scrap material being contained in suitable boxes.

At *B* and *C* a sectional and side elevation of a common type of battery house is given. The shelves *a* are arranged on the inside walls, giving a maximum of room for the batteryman's operations. The walls are lined with felt, asbestos, or similar material, *b*, for protection from the varying temperature of the outer air. With this arrangement inspection is rapid, and safety from high water assured.

CHAPTER VII.

THE TRACK CIRCUIT.

The track circuit includes that part of the control feature which is affected by the presence of a train within a block. It consists of insulated sections of track across which relays and batteries are connected so that the energization of the latter cannot be effected when the rails are connected by a pair of wheels and axle, or by other conditions which have been predetermined as dangerous to a rapidly moving train.

The simplest imaginable track circuit, combined with an old style of disk signal, is shown in Fig. 93. The section of track,

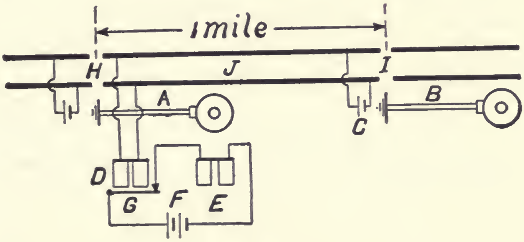


Fig. 93

J, is insulated from the adjacent track sections by the insulating joints, *H* and *I*, and is connected to a relay, *D*, and battery, *C*. The latter thus energizes *D* through the rails as a circuit. This causes the armature, *G*, to press against a contact in series with which is an electromagnet, *E* (controlling the clockwork which operates a banner in signal *A*), and a local battery, *F*. If a train occupies *J*, *D* and *C* will be short-circuited, thus deënergizing *E* and holding the clockworked banner at danger or stop. *B* is another similar signal at the subsequent block; train movement being in an easterly direction.

Continuing the application of the track circuit principle, we have in Fig. 94 a more comprehensive arrangement for tower

application than has been heretofore considered. A track relay, *G*, controls movements of the distant semaphore and is connected through the track to battery *F*. When the home signal, *H*, is at clear, the controller, *B*, is on closed circuit, and therefore determines (depending also on the position of the magnetic circuit controller's (*A*) armature) the current which flows through the control electromagnet, *D*, from battery *C*.

If a train be on section *T*, then the track relay at *G* will be deënergized, and the distant blade will move to caution. Also, battery *F* will be short-circuited, hence the armature of *E* must fall, which, in consequence, demagnetizes both *D* and *A*. If the operator should move the armature of *A* up, it will not remain there, owing to *C* being still on open circuit. Thus the

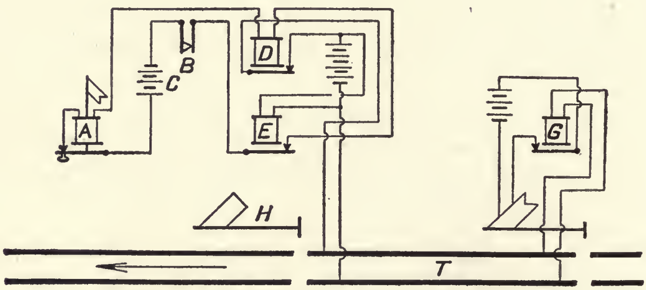


Fig. 94

home signal cannot be cleared except with full knowledge of the electrical indications.

Before track circuits were introduced, track instruments were employed to effect the circuit changes incident to the movement of a train. In purely automatic practice they have been abandoned, but are still used where track bonding has not been resorted to for minor electrical purposes, such as the ringing of a bell, or movement of an indicator. Fig. 95 shows this device in section, it consisting of a hollow upright placed a short distance from the rail, which contains a rod, *C*, forced downward by a spring and carrying at its upper end a contact button which engages in its upward position with the springs, *A* and *B*, to which the circuit wires are connected. When a train passes over the rail, *A* is connected to *B* by the action of the lever, *D*.

These contacts are in series with the device operated, and were formerly in the signal-control circuit.

The track circuit which would be afforded by ordinary rails is unreliable, owing to the poor electrical contact of the fish plates and abutting rail ends. It is evident that a single open contact such as that caused by the scale or oxide usually covering rails, would suffice to break the electrical continuity of the track circuit and render the signal system inoperative. Passing trains and the consequent vibration serve to increase this unreliability. For this reason, rail bonds are used to establish the electrical connection of the adjacent rails.

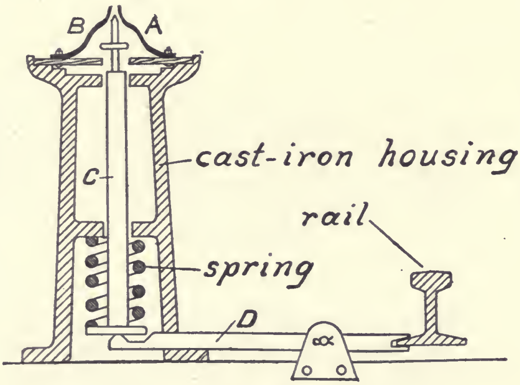


Fig. 95

In Fig. 96 the method of applying bond wires to two butting rail ends, *A* and *B*, is shown. The fish-plate, *F*, is bridged over or shunted by two bond wires, *C–C*, which are usually No. 8 B.W.G. galvanized E.B.B. iron, dependence not being placed on the contact of the former. The connection is effected by channel pins, *D*, one of which is shown at *E*, these being driven in a $\frac{5}{16}$-inch hole drilled in the web of the rail, with one end of the bond wire. The channel pin is recessed and tapered so that when driven home it grips the wire with considerable force. The wedge compresses tightly around the wire, thus producing a large contact area, the hole in the pin before driving being slightly larger than the diameter of the wire. The operation of driving also cleans the pin, the wire, and the rail; thus affording a good electrical contact, which is impervious to rain or dust. A section of the rail and channel pin is given at *G*.

Riveted bond wires are sometimes used, although the consensus of opinion is that they are not so reliable as channel pins. A riveted joint is illustrated at H in the above figure, a rivet being shown at K, the latter being upset in a hole drilled in the flange of the rail. No. 6 B. & S. copper wire is used at planked highway crossings, tunnels, or other damp localities when rivets are used.

In some cases bond wires are placed beneath the fish-plate; in others, outside the latter. The advantages of the first are the protection afforded the wire from mischievous persons, who often force the loose wire up on the face of the rail to be cut off

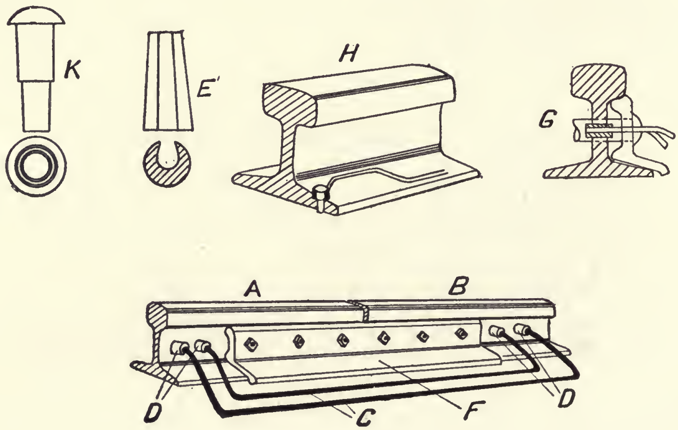


Fig. 96

by a passing train; and also from the operations of the maintenance-of-way corps. The disadvantage is the ease of oxidization, caused by the entrained moisture, and the labor of inspection. The second method has a reverse order of advantages and disadvantages.

When a track relay fails to be energized, after a survey has shown that the track battery is in proper condition, it is necessary to inspect the bond wires on both rails of the entire section, to locate the open circuit. With bond wires placed beneath the fish-plates, this is a laborious process, since each bond must be pulled to determine its continuity. With open bonds it is merely necessary to glance at the wires to discover any break in

the circuit, riding on the rear of a train giving ample time for inspection.

The number of bond wires used at a joint is a matter of individual opinion, but usually two are employed. With covered bonds, the general practice is to use one, while at grade crossings, bridges, and tunnels, three are used, to decrease the liability of an open circuit, due to the vibration and moisture evident under these conditions. Continued vibration results in crystallization of the metal at the junction with the rail; and when a break occurs, it is difficult to detect.

A representative installation at a switch or crossover is shown in Fig. 97. The trunking, *A*, shown in section, carries the insulated leads from the switch instrument, *B*, and the track connec-

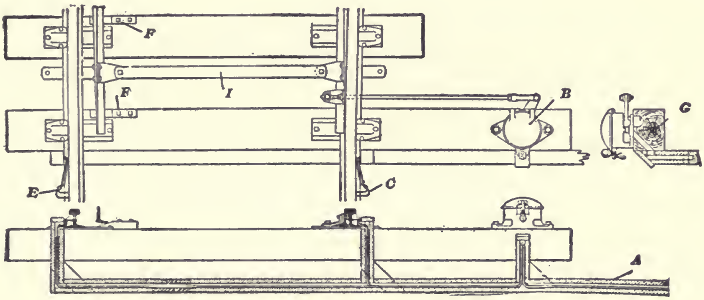


Fig. 97

tions, *E–C*. When the switch is open, *B* short-circuits the track, thus giving the block the same condition as that obtaining when a train is in this section. The switch-point rail rides upon two or more wedge blocks, *F*, that prevent it from coming in contact with the rails at *E*, from which it must be insulated when the switch is in its normal position, as the point rail is in electrical connection with the rail at *C*, through the uninsulated cross-bar, *I*, and the remainder of the rail. An end elevation of *B* is given at *G*. The short-circuiting action of the point rail cannot be depended upon; otherwise the switch instrument would not be used. This is an important consideration, as the open switch must hold its home signal at danger.

The same object is obtained in a line-wire system by opening the signal circuit when a switch is open. This is accomplished

through the arrangement shown in Fig. 98. The wood, *w*, is of a width conforming to the number of contact springs, *n*, used. One of the latter is used for each of the circuits, and it makes and breaks connection by its end, *a*, with a stationary contact piece, *h*. This is effected by the small insulated roller, *f*, which is operated by the switch movement through the pivoted lever, *m*. When the switch is closed, the end, *a*, is in contact with *h*, and when open it is disengaged from the latter, due to the removal of the roller from the hump in the spring. One circuit wire is connected to *n* and the other to *h*. On double-track lines, four contact springs, which are in series with home east, home west, distant east, and distant west, are often used.

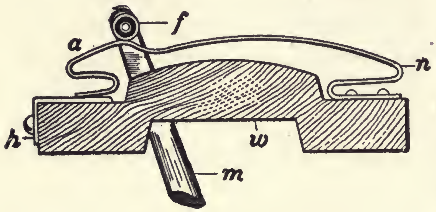


Fig. 98

Since cross-bars and switch rails would ordinarily short-circuit the track, it is necessary that insulation be introduced in these members to maintain the normal electrical isolation of the rails, which are of opposite polarity. As the track voltage is very low, the insulation resistance need not be relatively high, as is required in power circuits. For this purpose fiber is almost universally employed, due to its economical initial cost and subsesquent ability to withstand excessive pressure and vibration. Several schemes of switch construction are in use which eliminate the use of insulation at these points. One very meritorious arrangement was described in connection with Fig. 97.

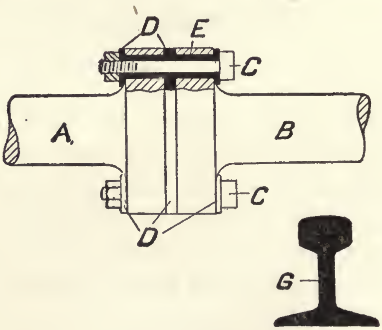


Fig. 99

In Fig. 99 a standard type of switch-rod insulation is shown. The rod is divided into two parts, *A* and *B*, the adjacent ends being secured mechanically by the bolts, *C*, and insulated by the

fiber bushings, *E* and strips, *D*. Adjacent rail ends in an insulated track section are separated by fiber sheets of the same shape as the rail section, as at *G*. The rails are held either by wood splice bars, or the regular steel fish-plates are supplemented by fiber sheets conforming to the rail sides. The bolts passing through the rails are insulated by means of fiber bushings. Where special reinforced fish-plates are used, a more substantial disposition of the sheet fiber is effected.

In Fig. 100 an Atlas rail joint is shown in section. Such a massive construction is required on the outer side of a curve for any rail section, and is used on roads having heavy rails, such as 90 or 100 pounds to the yard.

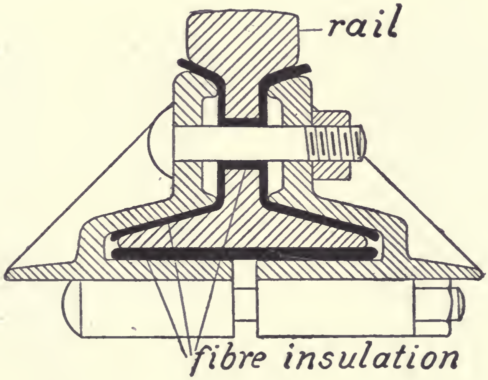


Fig. 100

Properly designed insulated joints are of the utmost importance in maintaining the integrity of the track-circuit equipment. Great trouble has been heretofore experienced with this adjunct, but experience and time test have sifted out the forms of joints that are fitted for this purpose. A good joint will have great mechanical strength, stand excessive vibration and wear, continue the proper alignment of the rails, have high insulation, and be easily renewed. Turnouts, local freight lines, sidings, and secondary tracks are sufficiently well insulated by wood splice-bars; while main tracks should have joints reinforced by steel plates.

In completing track or other circuits between a drawbridge and the abutments, it is not often advisable to use a submarine

cable, as the latter is not only too costly and undependable, but it does not break the circuits when the bridge is open. A circuit-breaking device, operated coincident with the movement of the bridge is a desirable feature, and it should have sufficient flexibility to prevent misalignment of the draw from affecting it. A so-called bridge circuit-coupler, which is used

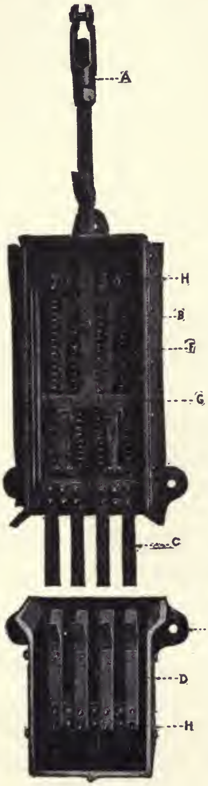


Fig. 101

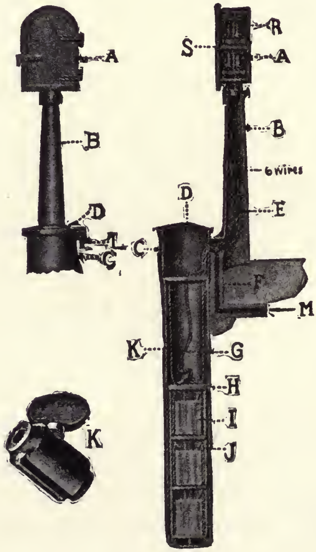


Fig. 102

to preserve the continuity of such circuits, so that when the bridge is open they will be opened, is shown in Fig. 101, and consists of two boxes, *B* and *E*, containing the connecting arrangements, either of which may be movable, one being fastened to the bridge end, and the other to a cross-tie at the rail ends. *A* is fastened to a lever of the bridge locking, and operates the fingers, *C*, through the cross-bar, *G*, so that when the bridge is to

be opened, the contact fingers, C, can be withdrawn from D, thus breaking the respective circuits. Flexible cables, F, allow a wide range of movement of C, the bridge circuits being completed through the binding contacts, H.

One method of installing track cells and relays is shown in Fig. 102. Within the cast iron chute, C (which is embedded in the earth near the track to such a depth that only about one foot of the top appears above ground), the three cells, I, held in a wooden cage, H, are placed. This cage is raised and lowered by the rope, G. The wires, K, leading from the cells pass to the track by way of the trunking, F. Other wires, E, within the hollow upright, B, pass from the relays, R, to the track. These relays are placed upon the shelves, S, and in the design given

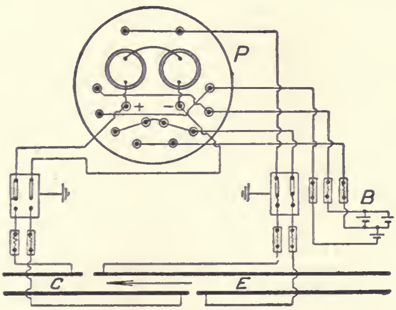


Fig. 103

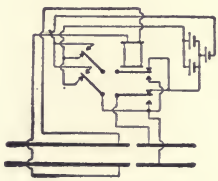


Fig. 103 *a*

are of the polarized and neutral types. The number of wires, M, will vary; in a double-track system there would be ten or twelve, although eight only are shown in the figure, which is for single-track. The number also varies accordingly as the section is at a signal or not; in the former case more wires being used. For the batteryman's convenience and for protection, a cover, D, provided with a lock, L, is added. The casing, A, is of cast iron, and both water and insect proof. Sometimes the track chute is separate, consisting of a simple cast-iron cylinder. At K a connector, which is soldered to the leads at the cells, is shown. The groove at the side is for the reception of the soldered wire.

In Fig. 103 the relay and track connections at a cut section on a normal clear, wireless, two-arm home and distant system appear, the diagram of circuits being given at A. P is a polarized

relay having two contacts in multiple on both polar and neutral armatures. The track battery, *B*, has two components, the greater ampere-hour capacity (of a given polarity) being connected to the track during the normal operation, which is when the semaphores are at clear. When a train occupies either section *C* or *E*, section *E* will be short-circuited by the action of the neutral armature contacts when the magnets are deënergized. When the distant blade at the preceding signal is at caution, the ampere-hour capacity (at the opposite polarity) of the connected track battery, *B*, is least, since this occurs only when a train occupies the distant section.

In Fig 104 the track and other connections at a normally clear wireless, with overlap, banjo-disk home signal, *S*, are shown. *R* is a polarized relay, the distant signal being placed

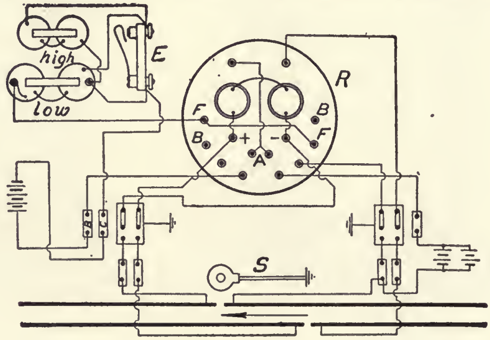


Fig. 104

at a relayed cut section. Such a scheme of connection is also used for a distant with a home in the rear, the latter having a separate distant signal. An electromagnet energizes the disk armature, this magnet having two windings, one of high resistance, and the other of low resistance. The high-resistance coil is connected in shunt with the contacts of the normally open spring-switch, *E*. When the signal is at danger this shunt is closed, thus short-circuiting the high-resistance coil and leaving in circuit the low-resistance winding. This produces a high initial current discharge, and consequent torque, when the front contacts at the relay are closed, insuring the proper clearing of the banner. When once cleared, the latter can be held in this position by the low energy of the high resistance winding. At the connection points, *B* is the free battery terminal, and *C* the common.

CHAPTER VIII.

CONTROLLED MANUAL SYSTEMS.

In the manual system of block signaling, the signals are operated and controlled solely by the tower attendant, there being no automatic control of the indicating functions. In the controlled manual system, which is intended for long block sections, the movements of the signals are effected by the operator, but these movements are controlled by electrical devices whose sources of current are in various track and line circuits.

In its usual form, this latter system consists of a number of electromagnets whose moving systems are so mechanically connected to the levers they control, that movement of the latter is prevented unless the block covered is in the proper condition for such movement. This is effected by giving the operator at one end of the block electrical control over the lever movement at the other end.

Thus, if the operator at 17 allows the movement of a train to 18, and then throws his signal to the danger position, he cannot throw the latter to clear until the operator at 18 unlocks his lever (17's), which 18 will not do until the train has passed out of the block, automatic arrangements preventing this unlocking, even if it were attempted. These latter accomplish this object by an electromagnet controlling the lever at 17, in series with which is a battery at 18, the line wire of this circuit being either broken at one of the various cut sections of the block, or at the section of the next block at 18, which has a track-relay back-contact in series with this battery, so that the locking magnet is not demagnetized until a train enters this section.

This latter arrangement is given in diagrammatic form in Fig. 105. Track relay *b*, at section 18*a*, normally holds its armature in the position shown. When a train, passing from 17 to 18, arrives at 18*a*, by short-circuiting track battery *c*, *b's* armature

closes the circuit of *d*, thus energizing *a* and releasing the locking function, *e*.

Under the permissive system, however, this arrangement would not give adequate protection, for, should a train be allowed to pass 17 before the previous train has reached 18, then when the latter arrives at 18 the locking function at 17 is released, thus giving a clear signal to the next train entering front section 17–18. To prevent this confusion, a track relay and contacts may be interposed in the latter section, thereby approaching more closely to an automatic system. This would be disadvantageous, however, in taking away, in this case, the requisite control of conditions from the tower operator.

In the manual control system brought out by Coleman, a combined track and wire circuit is used to control the movement of

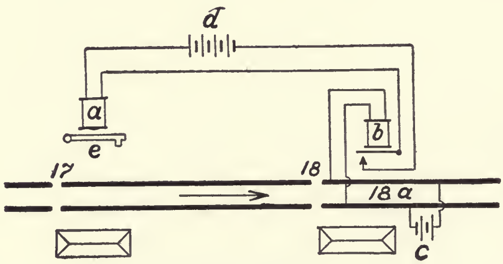


Fig. 105

mechanical signals. This arrangement will now be outlined, but not the actual mechanical construction of the devices used; the relations of the circuits and functions to automatic circuits being the principal object of this description.

In Figs. 106, 107, and 108 the arrangement of connections and a diagrammatic representation of the functions of the apparatus is shown. Fig. 106 gives the circuits at the first block station considered; Fig. 107, at the second station; and Fig. 108, at the third station, the fourth and all subsequent stations being entirely similar to the third in the arrangement of accessories and circuits.

In Fig. 106 signal arm 5, controlling the home block, is operated by lever 1, which is pivoted at 2, through the interposition of the usual mechanical accessories, and also the electric slot, 13. This slot prevents electrically the movement of the

signal arm when unfavorable conditions exist, as will be shown later. The locking arrangement consists partly of a sector casting, 6, having a lug, 10, which is connected by a link to the slotted section, 18, the latter being moved whenever the signalman, by squeezing the hand piece, 3, attempts to unlock the lever and subsequently throw the latter. The movement of the sector is governed by the electromagnet, 9, through the finger, 7, and the links, 8, connected to its armature.

In addition to 9, there is a circuit-control electromagnet, 12, and also the relay, 14, connected to the track. The arrangement of accessories at station 2 is somewhat similar to the above, and

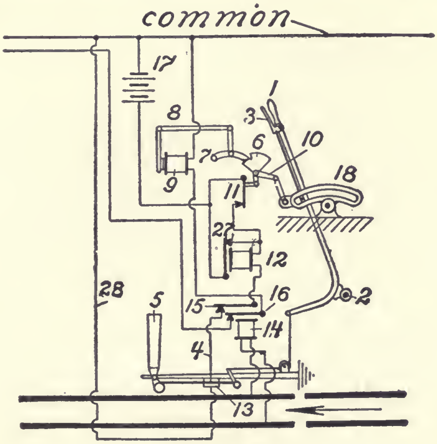


FIG. 106

contemplates in addition a sliding semaphore, 26, and a switch, 19. The connections of the electric slot at this signal are not shown, as it should be remembered that these circuits are traced out only so far as they affect the signal at station 1.

The electromagnet, 9, is connected in series with the line wires and with one of the front contacts of the track relay, 14. The line wires pass to the make and break arrangement 20, operated indirectly by the switch lever at station 2, the battery, 21, being in this circuit; hence 9 will not be energized unless the sector block, 22, is in the normal or danger position, as shown. The circuit of 9 will thus be broken at 20, and finger 7 will prevent motion of the sector block, 6, thus effectually locking signal 5 in the danger position.

Hence, before 5 can be cleared, the operator is required to summon the operator at station 2 to put his signal in the normal or stop position. Thus the apparatus requires that the block covered by 5 be closed at its outgoing end, thereby preventing a train from receiving a single permission to pass through two blocks. When a train is to pass from 1 to 2, all conditions being favorable, the operator throws lever 1, and consequently signal 5, the train then passing this signal. This causes the track battery 25 to be short-circuited, thus deënergizing relay 14, thereby breaking the circuit of 9. This allows the finger, 7, to drop, preventing motion of sector block 6, and consequent

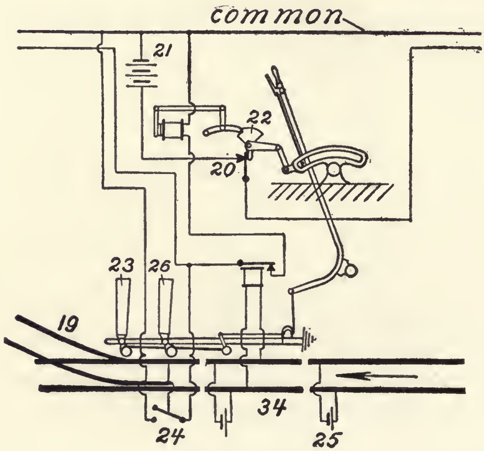


Fig. 107

unlocking of the lever. Thus signal 5 cannot be thrown to the clear position until the train has passed out of the block and restored contact 16 to its normal position by removing the short circuit from the battery.

Since the train cannot pass out of the block until the signal, 23, has been cleared, it follows that when this occurs the circuit of 9 will be opened at 20; hence, before the signal, 5, at station 1 can be again cleared, the train must pass out of the block of 23, and 23 must be thrown to the danger position. It is evident that a careless operator might throw the signal at station 1 to the clear position, and thus allow another train to enter the block before the first had passed out of it. But this is prevented by the

action of the electric slot, which throws the signal to the stop position when a train has entered its block independently of the operator. Thus the connection between the lever and the semaphore is not positive, but depends upon the electrical conditions of the block. The circuit of this slot (which is operated by an electromagnet) is composed of the wire, 4, the second front contact of track relay 14, electromagnet 12, armature contact 27, battery 17, common line-wire. and wire 28.

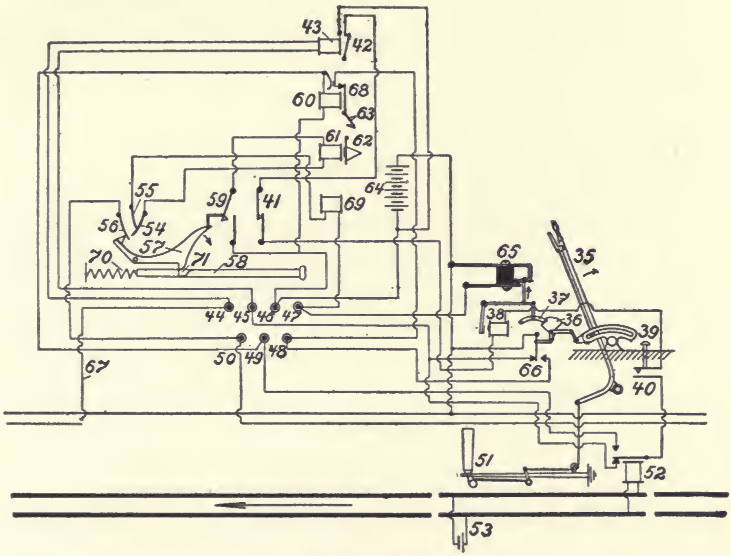


Fig. 108

When a train enters the block of signal 5, track relay 14 is short-circuited, thus breaking the slot magnet circuit at 15, and simultaneously at 27. This causes 5 to pass to the danger position, independent of the position of lever 1. The reason for interposing the independent double break is to preclude the possibility of the operator's throwing forward the lever to the normal position as soon as the train has passed into the block protected by 23, as this latter position of the train will restore the break in the circuit at 15 by the action of 14. Thus the connection between the lever and its semaphore is effectually broken until the proper conditions obtain. The consent of the

operator at 2 to allow movement of the signal lever at 1 is usually given by an electric bell or telegraph code.

It is evident that the circuit cannot be closed at 27 except by a current passing through the circuit independent of its own armature and contact. This latter circuit is formed by the wire, 4, passing from the slot magnet of 13, and includes also make-and-break arrangement 15, magnet coils 12, make-and-break mechanism 11, battery 17, common line-wire, and wire 28. Since 11 is controlled by sector block 6, and the links, 10, attached to 18, when the lever, 1, has been thrown to its normal or stop position, the circuit is closed at this point, it being open when 5 is in the clear position.

The motion of the hand piece, 3, which is necessary in order that the lever may be unlocked preparatory to its movement, produces motion in the slotted casting, 18, which indirectly breaks the circuit at 11, providing the sector block, 6, does not meet with the free end of the finger, 7. The closing of the circuit at 11 causes a current to pass through the coils of 12, thereby closing the circuit of slot 13 at 27. This becomes necessary in order that the slot mechanism may be held locked when lever 1 is to be moved. Otherwise the signal could not be cleared, since the mechanical connection is through the interposition of the slot. As 27 is in shunt with 11, the circuit is not broken by the opening of 11, so that the current from 17 continues to pass around the coils of 12.

As already stated, this system is applied to block sections of great length, so that if a continuous rail circuit were used, it would become needlessly expensive and complicated. As this combination of wire and track circuits is more readily comprehended, and simplifies what will follow, the above description has included it. In the circuits given with those at station 3, the track circuit will be omitted, except for a short working or setting length at each signal.

It has been shown that when a train passes signal 23 the control of 5 is restored to the operator at station 1, provided the operator at 2 has put his lever in the normal position. At station 3, on the other hand, 23 cannot be unlocked at once by the passing train, only the plunger, 58, being released. This latter must be actuated by the operator before the train passing signal 23 can short-circuit the track relay and produce an automatic

set of conditions at station 2. The operator at station 3 must actuate the plunger, 58, at the request of the operator at station 2, so that the latter may give a clear signal to the next train to occupy the block. In addition, the former must throw his signal to danger.

Since a train cannot pass 34 until 23 is cleared, and since 23 has been placed in the danger position to allow of 5's being unlocked, it cannot be thrown to the clear position without the permission of the operator at station 3. The apparatus by which this permission is given constitutes Coleman's machine, the mechanical construction of which will not be taken up.

Again considering the arrangement at station 3, it is evident that lever 35 cannot be thrown until the sector block, 36, can clear 37; that is, until a current passes through the electromagnet, 38. The floor knob, 39, is then pressed downward, which closes the contacts at 40 and connects one side of 38 with the common line-wire. When this occurs, we may trace up the circuit to the closed contacts at 41 and the open contacts at 42. These latter must be closed by energizing the electromagnet, 43, before the circuit can be completed through the battery, 64, and the common line return. As 43 is in shunt with the binding posts, 44 and 45, a current must come in over the line wires from station 2, and on the common line side through the armature contacts of relay 52. Hence, it is necessary that 52 be in an energized condition, that is, with no train on the section of track-battery 53. At station 2, 20 must be closed, then a current from 21 will flow through 43. With these conditions fulfilled, 51 can be cleared by throwing 35.

As above stated, 58 is a plunger which is moved in the direction of the arrow, normally held in the extreme inner position by a spring, 70, this plunger being provided for the purpose of allowing the signal at the next station to be unlocked. When 58 is pulled out to the position shown, the projection on the dog, 57, drops within the aperture, 71, in 58, thus breaking the contact of spring 55 with 54, and connecting 56 with 54. The spring contacts, 59, are closed, at the same time those at 41 being opened. The former is effected by the action of the rock shaft carrying the dog, 57, and the latter by the movement of a train.

The resistance coil, 69, is interposed in the circuit of 61, while 61 is an electromagnet which has an armature provided with a

swinging carrier, 62. When 60 is energized, its armature, 63, which carries a retaining catch, closes the contacts, 68, thus connecting 48 with 49. When 37 is raised by 38, the contacts of 65 are opened, thus disconnecting 47 from 64. When the train passes, 52 is energized, and its armature closes the lower contact, the operator returning the lever to its normal position. This opens the retaining circuit at 66, and in consequence, electromagnet 60, releasing the catch 63, allowing the word "Free" on a banner to pass before a glass aperture in the housing, which denotes that the lever at station 2 may be unlocked for a second train. Thus the dependence of one operator upon the other is shown. By tracing up the circuits, the reader will be able to deduce the remainder of the functions. A complete description of the apparatus would be too lengthy for this book.

On single-track lines, a modified form of lock and block arrangement must be used if the controlled manual system is employed. Trains bound in both directions must run alternately into sidings to allow passing, these sidings being governed by signals which are interconnected electrically. Block towers are placed as near as convenient to overlapping opposite sidings, into which trains proceed under given conditions. The operator at block tower 23, for example, governs the levers at 24, this consecutive arrangement being necessary for safety. It is evident, also, that each operator has control over trains moving in both directions.

In Fig. 109 the relation of such a single-track system, with the Leonard scheme of control, is shown. *D* is a track instrument (a device which closes a circuit when the wheels of a train pass over the end of a projecting lever whose other end operates a spring contact, as in Fig. 95) which closes the circuit of the battery, *F*, through the lock instrument, *E*. In this same circuit is a circuit breaker, *G*, which disconnects *E* from *F*. A circuit closer, *A*, is situated at the ends of the east- and west-bound sidings, and is connected to *E* and *F* by the line wires, *K*, *L*. (The west-bound apparatus is distinguished by small letters.)

The operator, to allow an east-bound train to proceed from 23, unlocks the signal lever at the latter point. The unlocking current passes over the line wires *w*, which connect successive towers. This function then remains locked until released by the track instrument, due to the effect of the passing train.

The line circuit at the same time is opened (by the circuit breaker, G, of the signal C), so that a west-bound train cannot enter the section, because the west-bound signal, B, is at danger, it being controlled by the battery at 23. If the locking function is not released by D, the train enters the side track, and the switch, S, must be closed by the brakeman immediately after the train passes the derailing switch, which is at A. This operation closes for an instant the unlocking circuit at A, which sends a current to the lock instrument from the battery, F.

If a west-bound train is to be allowed to proceed, permission and unlocking is first received from 25. The signal, C, is then cleared, which breaks the circuit of the track instrument

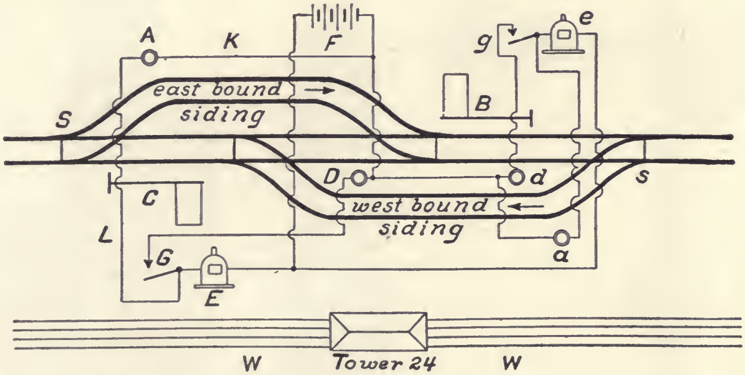


FIG. 109

and prevents the signal from being unlocked by a train until it has first been thrown to the stop position. Indicators are used at the switches to apprise the conductor as to whether he may proceed on the main line or take a siding.

The electric slot is a controlling device which automatically causes a mechanical semaphore to move to the danger position after a train has passed this signal. This arrangement prevents negligence on the part of the signal operator causing a rear end collision. Its function is thus similar to the rod slot which has been in use for many years on purely mechanical systems. Fig. 110 represents the application of a Union electric slot to a triple-lens mechanical signal. The semaphore, S, is secured to a pivoted casting carrying three lenses, L, night

indications being given by the lamp, *A*, the white light from which must pass through a lens when the signal is in a full or partial stop position.

This blade is operated by the rod, *C*, which passes into the slot box, *D*, and is connected mechanically (when a train is not in the block of the signal) with the rod, *C*. The latter

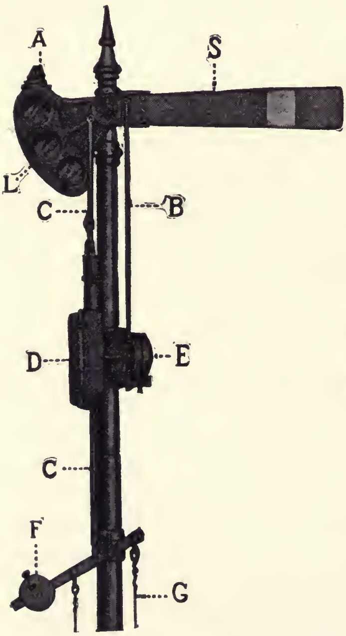


Fig. 110

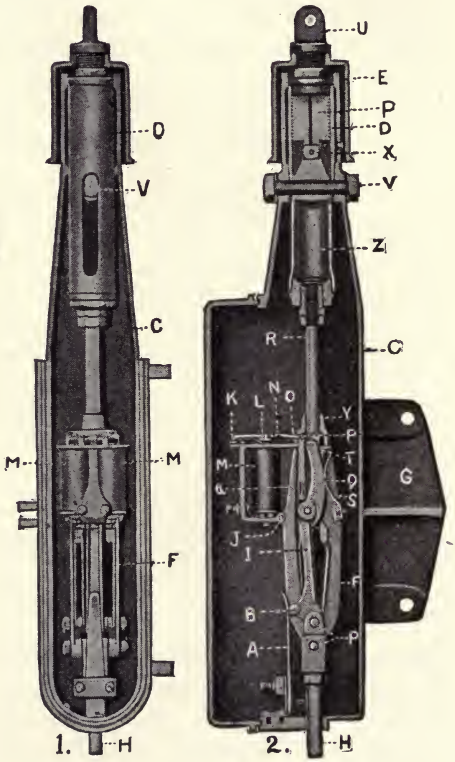


Fig. 111

is pivoted to a rocking lever counterweighted at *F*, which is connected to the signal lever by the steel wires, *G*. *E* is a circuit controller connected to the slot or control circuit of other signals, as will be shown later.

The slot structure and its weatherproof housing is shown in part section and part elevation in Fig. 111; 1 being a side and 2 a front view. When motion is imparted to the rod, *H*, by

the signalman, the frame, *F*, and the accessories attached to it move. The rods, *R* and *H*, are not connected unless the electromagnet, *M*, is energized, when the signalman has full control of the semaphore. On the other hand, if *M* be deënergized, the connection between *R* and *H* is broken and movements of the latter will in no wise affect the former, hence the blade cannot be moved.

To the frame, *F*, the electromagnet, *M*, spring *S*, pivots *P*, and guide sleeve, *Y*, are secured. The link, *I*, moves around the upper pivot as a center, while the spring piece, *A*, by pressing against the projection, *B*, holds *I* in the position given. The roller, *W*, which is attached to *I*, engages in a recess with the pawl, *Q*, the latter being pivoted in a recess on the rod, *R*, at *T*. When current is not passing through *M*, the centers of *T*, *W*, and *p* are not in the same straight line. Therefore, if a pressure be applied upward on *H* (which will occur when the signalman attempts to clear the signal), the roller will move to the left by the action of the link, *I*, on its pivot. Hence this roller disengages with the pawl (which cannot move further to the left) due to the weight of the unbalanced semaphore; and *H* moves up or down without engagement. The electromagnet has a movable armature, which is held at one end by the stationary pivot, *K*, and at the other end by a movable pivot, *N*. *O* is a short link secured rigidly to the lever, *a*, these being pivoted at *P*. The armature is normally held upward, and away from the pole tips by the spring, *L*. The pivots, *K*, *N*, and *P*, are normally out of line, hence, when an attempt is made to force *W* upward, *a* allows *Q* to be disengaged, thereby preventing motion of *R*.

If *M* be energized, due to the block protected by the signal being clear, the tension of *L* will be overcome and the armature will be in its extreme lower position. This forces the roller into the recess in *Q*, and if movement be imparted to *H*, *Q* will also move, and consequently *R*. If this motion were too rapid, due to too energetic motion of the signal lever, it is evident that the inertia of the parts would in all probability break some part of the mechanism. To prevent this occurrence, a damping cylinder or dashpot is interposed. It consists of a shell, *D*, having a carefully fitted plunger, *P*, the latter being stationary, and pivotally secured to the bolt, *V*. The shell is fastened to the coupling, *U*, connected to the semaphore rod, and has an

extension, Z, which is slotted and forms a guide with the bolt, V. An adjustable valve, X, through which the entrained air (on the downward motion) bleeds out with more or less rapidity, according to the retardation desired, is provided; and a shell, E, forms a protection from the weather. The case, C, is bolted to the signal mast by the lug, G.

When R is moved upward, the entire frame and its appurtenances, such as the magnet and pawl, also move. The spring, A, only presses upon B at the commencement of the motion, so that in case M were demagnetized by the presence of a train in the block or an opened switch, when the signal was at clear, its armature would rise, and the pawl be released, thus causing the signal to assume the danger position independent of the operator. The latter then replaces his lever upon receiving the indication by the action of the circuit controller. If the signalman attempted to throw the signal to the clear position, he could not succeed, since H has no connection with R. However, H, M, F, and the roller will move upward, but this does not affect the semaphore's position. The electric slot and its modification occupies an important position in composite manual and automatic signaling, and is employed extensively on signals governed from centralized towers.

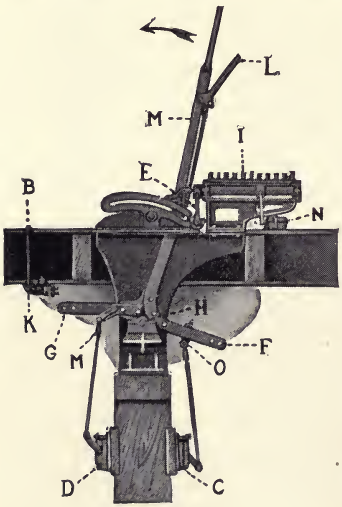


Fig. 112

The method of applying circuit controllers to the levers of the controlled manual and semi-automatic systems is shown in Fig. 112. The lever, M, pivoted at H, has two extensions, F and G, to which the wires or bars operating the signal are secured. In order to unlock this lever, the latch must be opened by moving the pivoted member, L, in the direction of the small arrow. N is an electric lock or slot, connected by a link to one of the rock shafts of the interlocking machine, I. This rock shaft is also linked to the unlocking segment of the lever by the rod, E.

C and D are circuit controllers operated respectively by the toes, O and M. B–K is a floor button which closes a circuit connected to the distant cabin, and serves as a means of communication and releasing between the operators. The functions and operation of this arrangement will be apparent from descriptions already given.

One application of a duplex rotary circuit-controller, E, is shown in Fig. 113, it being fastened to the signal pole and operated through the home semaphore by the rod or connecting link, M. I is a mechanically operated home and distant, the electric slots, A and C, securing the semi-automatic control, and being energized by battery D through the interposition of the

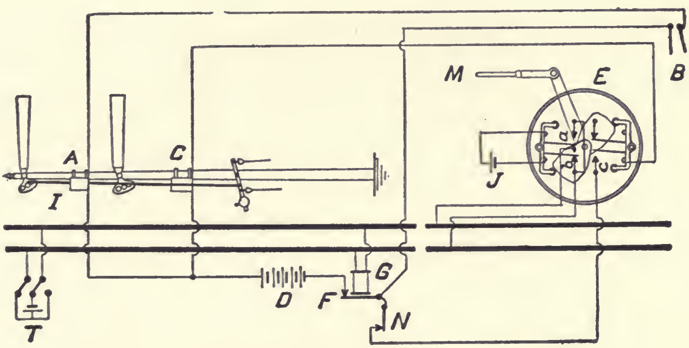


FIG. 113

polarized relay, G. A is controlled by the neutral armature, F, and C by both the polarized, N, and neutral armatures in series. The controller, B, is in series with the home slot, and by being open when the semaphore is not at clear, effects a saving in current consumption, besides giving an additional manual control if desirable.

When the home blade is at stop, contact B is open, hence C is deënergized, so that the distant cannot be cleared unless the former is clear; a similar condition existing when either F or N is open, which will occur if T is short-circuited or of the wrong polarity. Contacts a and b effect a polarity reversal of the track battery, J, by motion of M. This polarity change occurs at every motion of the home blade, thus controlling the preceding signal. The fourth contact of the controller is unconnected,

the construction allowing a nearly complete stroke of *M* before a change in connection takes place.

A circuit controller for operation by the foot is shown in section and elevation in Fig. 114. To the floor or other convenient support, *B*, the pivoted lever or foot piece, *A*, is secured. The opposite end of this foot piece carries a roller, *H*, which presses against a curved spring strip, *G*. Normally, *G* is in contact with *F*, or *E* is connected to *D*. When *A* is forced downward, *E* is connected to *C*, and *D* is open-circuited. This device is applied wherever it is desired to close one circuit simultaneously with the opening of a normally closed circuit.

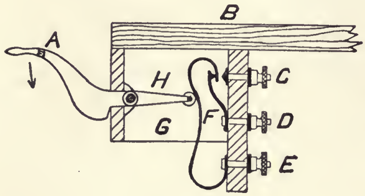


Fig. 114

CHAPTER IX.

MOTORS, RELAYS, ETC.

Signal motors are of small size, series wound, and for direct current only. As they are generally operated by battery current, the terminal voltage is of necessity low. It is not practicable to operate motors over line wires of any great length, owing to the great loss of energy in the latter, and the low starting torque of the motor.

The sizes of motors used vary from 65 to 150 watts, or one-twelfth to one-fifth of a horse-power. From 10 to 20 Edison or Gordon cells are used to operate these motors, so that, should the applied voltage vary from 7 to 14, the full-load current will vary from 9 to 5 amperes in the smallest motors to from 20 to 11 amperes in the one-fifth horse-power unit. The larger motors (as in all-electric systems of interlocking) are supplied with current from a storage battery having considerable potential, so that the above currents are much reduced. Derailing and switch movement motors are at a maximum of about one horse-power, although they operate normally at about 420 watts (7 amperes at 60 volts, or 4 amperes at 110 volts).

In Fig. 115 a standard form of signal motor is illustrated. *F* is the laminated field, which consists of a large number of stampings of soft iron held firmly between heavy end pieces of similar contour. The exciting coils, *W*, are connected in series with the armature, *A*, through the brushes *B*, and the commutator, *C*. *S* is a removable transparent glass end-shield, which effectually prevents dust and moisture from collecting on the moving surfaces, also allowing inspection from time to time. *P* is the brake pulley and *M* the brake mechanism, whose function is described in connection with Fig. 117.

The laminations of soft iron on both armature and field, having a high permeability, allow of a greater flux density than could be obtained from solid iron, at the same time reduc-

ing to a minimum the eddy-current loss. The armature shaft carries a pinion which engages with the gear train of the clearing mechanism. The motor is provided with a base by means of which it is bolted to the frame. Semaphore signals in general use motors that have become the standard for small sizes in electrical power application, with but slight modification.

There are a number of combined electrical and mechanical methods of applying a brake to a motor armature for the purpose of rapidly bringing it to rest; so that the semaphore movement will occur within a minimum time and at a uniform

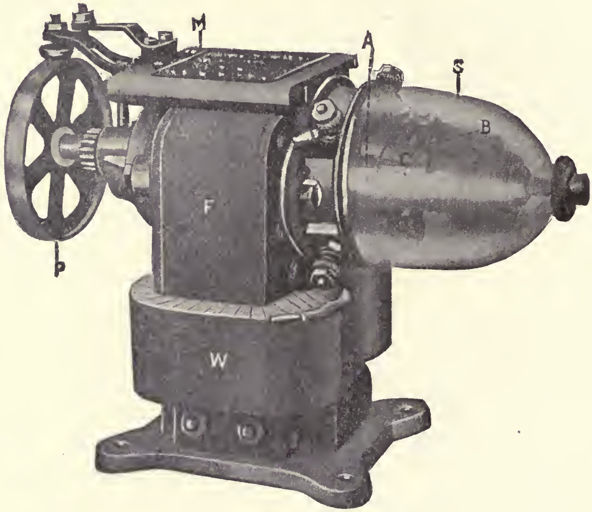


Fig. 115

rate throughout the entire angle of motion. Obviously the most effective arrangement will operate immediately upon current cessation, and release upon the commencement of its flow. Two such schemes will now be considered.

In Fig. 116, *a* is a friction wheel keyed to the shaft, *i*, of the motor. In series or shunt with the motor or its field is an electromagnet, *g*, whose armature, *f*, pivoted at *d*, and weighted at *e*, carries a shoe or brake, *b*, pivoted at *c*, and conforming on its inside surface to the circumference of *a*. When the current passing through *g* (and consequently the motor) ceases, *b* will engage with *a* and bring the latter to a stop within a time

proportional to the relative position of *c*. The disadvantage of this device is the multiplicity of parts and the waste of energy in exciting *g*.

In Fig. 117, which is a brake frequently applied to semaphore motors, *F* is the field pole of the motor, *S* the armature shaft, and *P* a pulley keyed to the latter. *B* is a rubber held normally against the face of *P*, by the adjustable spring, *H*. *B* is carried on the iron rocking pieces, and its position determined by the adjustment, *G*. When current passes through the motor, the iron prong or strip is attracted to the tips of *F*, and by overcoming the tension of *H* releases *B*. When current

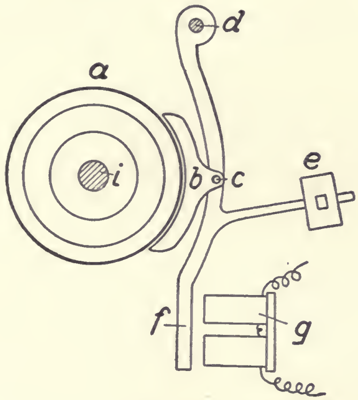


FIG. 116

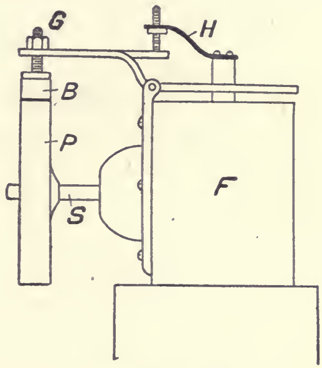


FIG. 117

ceases, the cessation of the flux in *F* releases the prong, causing *B* to be forced against *P*, and rapidly overcoming the inertia of the armature.

Soft iron disks affixed to the armature shaft have also been used to retard the rotation of the latter. The disk moves between the poles of a strong electromagnet, and the reaction caused by the setting up of eddy currents in this disk effectually brings the armature to a stop.

A motor brake and the circuit arrangement thereto is shown in Fig. 118. *A* is the signal-control relay (normal danger) in series with the main battery, common, home line-wire, and track-relay armature. It has front and back armature contacts, *C* and *B*, having a common connection. *B* is in series

with the motor, so that the latter is short-circuited upon itself. *H* is a circuit controller whose movable contact, *E*, travels in the direction of the arrow when the signal is clearing. When *A*, is energized, a current passes from *D* to *G*, *H*, motor, and *C*. When the semaphore is about cleared, *E* connects *G* and *I*, thus sending a current through the brake magnet, *J*, and bringing the motor armature to a stop, current being cut off simultaneously from the motor circuit. When the semaphore returns to danger by the deënergization of its slot and *A*, the current set up by the counter e.m.f. through the low resistance circuit, *H–E–F–B*, produces the desired retardation.

For a given output, the resistance of motors increases as the voltage of the circuits to which they are applied is increased.

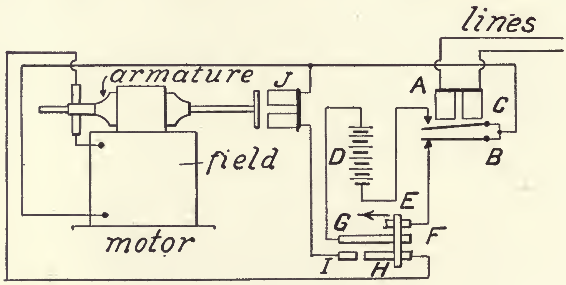


Fig. 118

In small motors, the higher the average voltage at which they operate, the more efficient do they become. It is not so much the actual resistance of the motor itself which gives the increased efficiency, but the relativity of this resistance to the total resistance, external to the motor terminals, such as that in the wiring, relay contacts, batteries, and connections. Hence, the greater the operating voltage, the less will be the percentage of loss in these subsidiary devices, and the greater the available energy manifested in motor torque.

A transmission gear for throwing one or more semaphores to clear is outlined in Fig. 119. The motor, *M*, drives the sheave, *S*, through the gearing, *G*. *B* is a brake magnet whose armature lever when deënergized bears against the wheel, *W*, keyed to the armature shaft, thus preventing rotation of the latter, the adjustable counterweight, *C*, providing a time limit.

This arrangement is fastened near the base of the signal pole and provided with a weatherproof cover.

Numerous types of relays are used in signal practice, all of which embody certain generic features. Great variations exist, however, in the resistance to which they are wound, in one case a four-ohm winding being standard, and in another a 3000-ohm winding is applied.

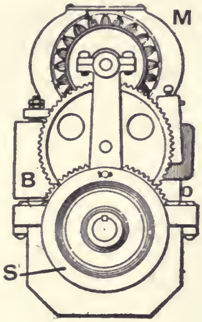


Fig. 119

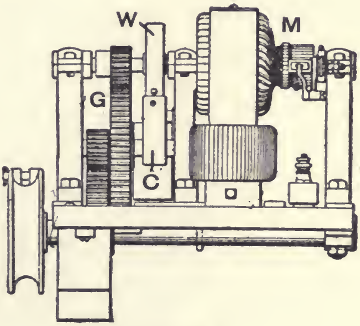


Fig. 119*a*

In Fig. 120 a Taylor neutral-track or control relay is shown. The magnets, *M*, are carried on the cast brass base, between which and the sub-base are the armature and contacts, the latter being protected by a cylindrical glass ring, *G*. The contact fingers, *H*, are fastened to the armature, *A*, by lavite bushings, *L*, and make scraping connection with the front contact, *F*, and back contacts, *B* ; these being introduced in the external circuit by the binding posts, *C*. The coils of *M* are connected to posts, *P*.

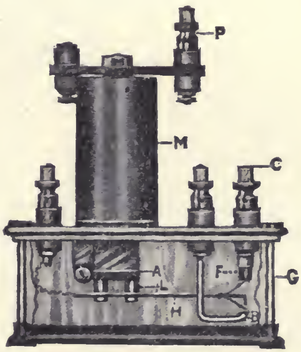


Fig. 120

Fig. 121 shows in section and elevation a polarized type glass-enclosed relay having a neutral armature, *C*, and a polarized armature, *G*. The latter swings about a pivot, *B*, the direction of motion depending upon the polarity of the poles of magnets, *M*. *A* is a permanently magnetized rod of steel, one end of which is fastened in the yoke, *H*, the

other projecting to the level of the pole tips of *M*. The neutral armature is given a vertical movement, and has front carbon contacts at *D* and back contacts at *E*, through the flexible strip, *F*.

The operation will be evident from the plan of the contact parts in Fig. 122. When current in either direction passes through the magnets, the neutral armature, *G*, is raised, closing the front contacts, *D*. On cessation of current, the back contact only is closed. If the pole tip on the right hand side be of north polarity, and the same end of the polarized armature, *G*,

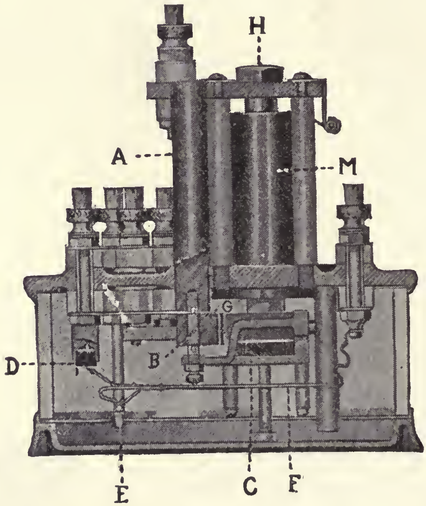


Fig. 121

be magnetized inductively from the permanent magnet so that it becomes a south pole, attraction will result and the armature will turn in this direction. The opposite end of the armature will be repelled from the other magnet pole, as the latter is of south polarity, the armature end also being south. This causes the contact fingers, *L*, to be forced against the carbon contact-buttons, *K*. A reversal of current will reverse these conditions.

Both armatures are pivoted close to the field poles, so that the required motion is slight, hence they are continually in a strong field when energization occurs, due allowance being

made for eliminating the effects of residual magnetism. Adjustment is not required, as the pivots are fastened to the pole tips, overcoming the variations due to expansion. The alternate polar contacts are in multiple, and contact made with a scraping motion, for self-cleaning. With a short armature motion, a wide break results, flexible copper strips connecting the binding posts of the armature fingers.

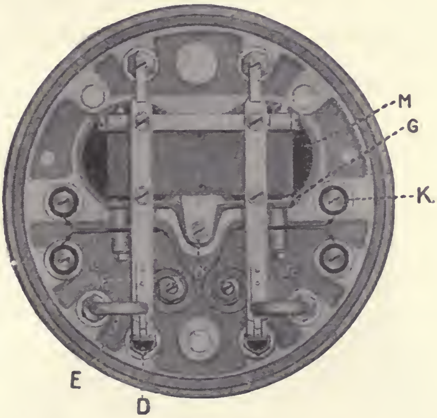


Fig. 122

Fig. 123 shows a relay designed for breaking circuits carrying heavy current at comparatively high potential (for signal circuits). The magnet coils, *M*, are connected to the track, or other control circuit; the working current being carried by the resilient strip, *E*, and carbon contacts, *C*. When the armature falls, a wide and rapid break is introduced, the back contact at *D* being then closed. *B* is a series magnetic blow-out coil, the poles of its magnetic circuit causing a powerful flux to pass across the arc, thus rapidly disrupting it; a slight movement of the armature, *F*, also produces a wide break at *C*. The mechanism is enclosed in a glass case, as the presence of dust or insects is inimical to its proper operation.

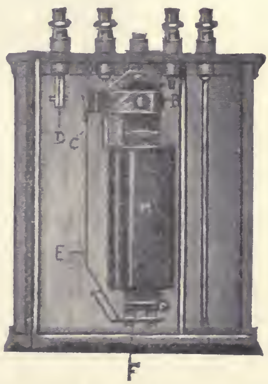


Fig. 123

The G. E. neutral relay, with the glass cover removed, is shown in Fig. 124. *M* are the electromagnets, which actuate the armature, *A*. The latter carries brass lugs to which the carbon contacts *C*, are clamped, these making and breaking contact with the flexibly mounted fingers, *F*, carrying ends of silver. The posts, *P*, are in connection with the terminals, *D–D*. A quadruple break is effected by this device, which is very satisfactory. The contacts cannot be fused by lightning, as carbon and a metal will not fuse together in such cases.

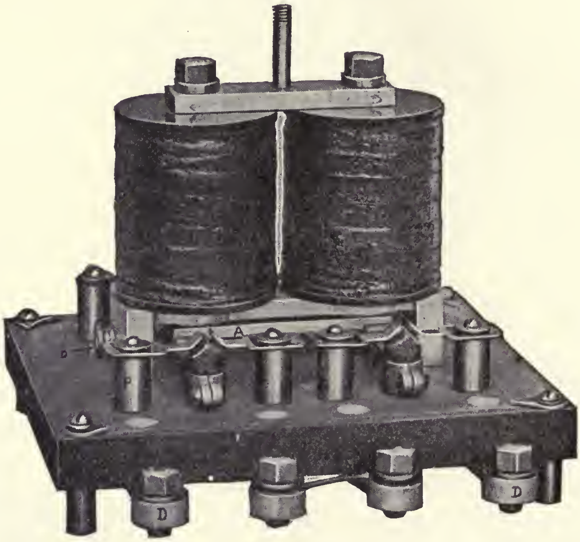


FIG. 124

The advantage of using carbon is that its oxide is a gas; thus it continually presents a clean surface, while the oxide of silver itself is a good conductor.

In order to eliminate the false conditions set up from relay contacts being fused together by lightning, the relay armature arrangement shown in Fig. 125 is used. The armature, *H*, of the electromagnet, *M*, having pole tips, *P*, is pivoted at *F*, and carries a depending member, *K*, at the pivot, *G*. Fastened to *K* is the spring contact strip, *B–E*, which normally is in contact with the connection *A*. When *B*, however, becomes fused to the contact button, *C*, this latter point acts as the

pivot, so that when M is demagnetized the weight of H and K causes E to come into contact with D. The signal magnet relay or battery is connected to D and C, so that when E comes into contact with D, it will be short-circuited, as this shunt has practically no resistance. This causes the signal arm to move to the stop position, thereby apprising the maintainer that something is wrong. Otherwise, the presence of a train in the section would not affect the clear position of the signal, since the release of the armature cannot open the circuit at C–B.

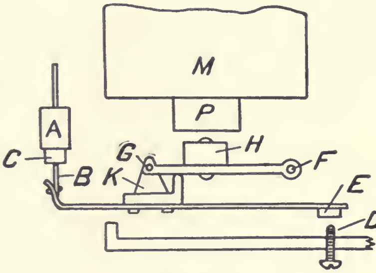


FIG. 125

Great care should be exercised in selecting the proper resistance value to which relays are to be wound, as upon this factor depends in a large measure the life of the batteries to which they are connected. Thus a 700-ohm relay will take but one-tenth of the current that one wound to 70 ohms would. Too high a resistance is not advisable, as the wire then must be of very small diameter, so that the proper number of ampere-turns can be put into the necessarily limited space between the cores. Fine wire is very costly and difficult to wind, while the slightest corrosion or mechanical injury results in an open circuit. Too large a size or wire, on the other hand, involves too great a current input for the production of the proper ampere-turns.

Individual cases require special determination of resistance; so that no fixed rule can be followed. It is sometimes advisable to introduce a German silver resistance spool, having a predetermined ohmic factor, in series with a relay connected to a battery of too high voltage, which is primarily intended for other purposes. Such a procedure should be avoided whenever possible, however, as the energy thus lost in the resistance is wasted. Relays in series must have resistances proportional to the work which they perform. For instance, a relay in series with a disk magnet must have a low resistance relative to that of the latter, otherwise too great a proportion of the available energy would be taken. Relays in parallel

must have high resistance so that the changed drop in potential resulting on one or more being thrown in circuit cannot materially affect the others.

Fig. 126 is a plotted curve showing the voltages required to operate standard track-relays of from 2 to 10 ohms resistance. Curve *V* shows the least voltage that should be applied to a given relay of a certain resistance in practice. This curve allows for operation under favorable conditions; with allowance

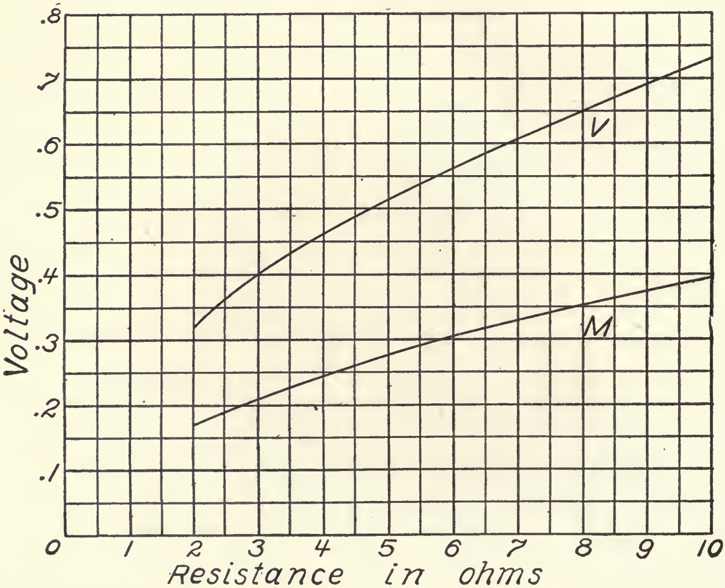


Fig. 126

for an average amount of leakage, due to the effects of wet weather, and rail proximity to stone ballast.

The curve, *M*, shows the minimum voltage that will lift the armature of the relay and produce contact with the fingers. This voltage curve allows only for a moderate amount of resistance of motion due to friction of the pivots, and will not lift the armature with cobwebs, interference by insects, or other deleterious opposition. On the other hand, the presence of residual magnetism will require a lower voltage for energizing the magnetic circuit; this, however, being an undesirable condition.

There is a sufficient interim of current cessation at the reversal of polarity in a wireless system to throw the signal at danger unless a slow releasing of the control armatures or slots be provided for. The slow-releasing slot is obviously the best solution of this difficulty, as external control fixtures are then not required. The home-slot magnets are therefore constructed with a soft copper tube interposed between the core and the winding, and equal in length to the core. Any change of current in the latter sets up strong momentary eddy currents in the tube, which oppose any change in flux through the magnetic circuit. The magnet is also wound to sufficient ampere-turns to produce a much greater flux than is actually required, so

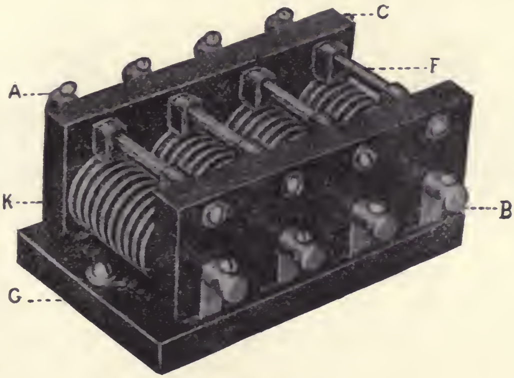


Fig. 127

this flux must die down a considerable amount before the armature is released. Should the circuit remain open after the mechanical pull of the armature becomes less than the opposition of gravity or the slot arm, the home semaphore will return to danger.

Important adjuncts in a line-wire system are devices to secure adequate lightning protection. They are particularly required to prevent relay points from fusing together by affording the discharge a shunt circuit to ground of lower impedance than by way of the former. A lightning or other static discharge is in reality a surging alternating current of enormous frequency and short duration. Such a discharge will overcome the high resistance of an air-gap rather than pass around a few

turns of coiled conductor, as the latter, at this frequency, offers an extremely high inductance.

A bank of four G. E. lightning arresters is shown in Fig. 127. The lines are connected to the posts, *A*, the instruments to the connectors, *B*, and ground to the plate, *G*. The choke coils, *K*, consisting of a few turns of heavy wire in an insulating form, are in series with the glass tube enclosed fuses, *F*, these latter being removable, and held between clips *C*. A discharge will pass from the points beneath the slate end pieces to the ground plate rather than around the coil. Jumping areas also occur between the lower parts of the convolutions and *G*, thereby increasing the factor of safety.

Another common form of arrester is illustrated in Fig. 128.

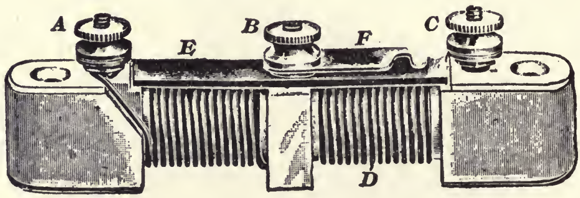


Fig. 128

Upon a porcelain form are wound two connected helices of bare wire, *D*, one end of which is connected to post *A*, and the other end to *C*. *B* is grounded, *A* connected to the line or track wire, and *C* to the instrument or wire desired to be protected. When a discharge enters at *A*, *D* offers such a high impedance that the air-gap between *E* and *D* is bridged before many turns have carried the current, thus conveying it to the ground. When a bank of such arresters is employed the ground plates are connected by the strips, *F*, but one ground wire being used. No provision is necessary to prevent grounding of the battery currents, since they are of too low potential to bridge this gap, as would be the case on a commercial lighting or power circuit.

CHAPTER X.

HALL APPARATUS.

THE enclosed disk signal has a number of meritorious features, among which are the protection of the moving parts against the weather, and the low energy required to operate the moving system. An electromagnet of comparatively small size operates the latter, the power required being insignificant (about 2.5 watts in ordinary cases). The external appearance of a post-type normal danger home and distant disk-signal, such as is used on the Lehigh Valley, is given in Fig. 129. *A* is the home banner, which consists of a red silk, cotton, or aluminum disk stretched on a ring having a diameter of about 18 inches; while *B* is the distant banner, which is of a green fabric. The inside back of the housing, *C*, is painted white, so that when the disks are in the upper position, the aperture in the case will show white. The case is usually painted black, so that the color of the opening may be seen for a considerable distance.

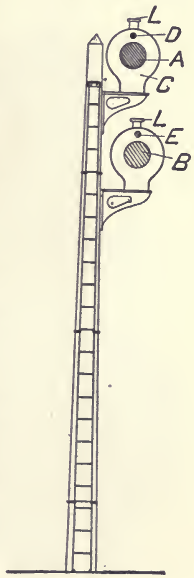


FIG. 129

Lamps *L* are placed in the rear of the apertures, *D* and *E*, before which spectacles of the same color as the disks pass, for night signaling. The tendency of gravity is to hold the disks in a position directly behind the glass-covered apertures, so that unless the magnets are energized, a color indication will be given to the engineer. Disk signals are purely color arrangements, in contradistinction to semaphore, or position and color signals. Where home or distant units on separate masts are used, the banjo is placed on top of, and centrally disposed with respect to the pole, which produces a more symmetrical combination.

Among the disadvantages of enclosed signals may be mentioned: the tendency of sleet or snow to obscure the disk, by covering the glass and thus giving a white effect; the direct reflection of the sun's rays in the engineman's eyes, preventing a clear view of the disk; and the liability of the glass spectacles falling out, due to their tendency to crack from the effects of the inertia of the moving system. Only the latter may be regarded as a dangerous feature, since all railroads require that a train stop when a signal is only partially or imperfectly displayed; which, while resulting in a certain loss of time, has not argued much against their introduction.

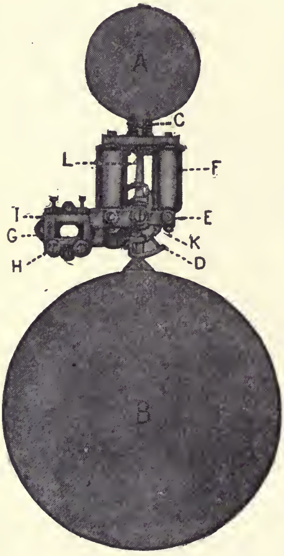


Fig. 130

Within the housing or banjo of the disk signal is placed the arrangement shown in Fig. 130, which constitutes the disk instrument. It consists of an electromagnet, F, whose armature, D, moves a member, L, to which the banner, B, of colored cloth for indications by day, and the disk, A, of colored glass for night indications, are fastened. D is pivoted at K, and its continuity of motion causes a greater flux to pass through the magnetic circuit by decreasing the sectional area of the air-gap. F is held in place by the brass piece I–E, this being secured in the iron base, G, by the eccentric washers, H, G being fastened to the inside of the banjo. The external circuit is connected to the binding posts, C. A and B move before clear glass apertures in the housing, a lamp being placed in the rear of A.

This type of signal mechanism is used extensively on the Lehigh Valley, Philadelphia and Reading, and Chicago and North Western. The disadvantage of the cloth banner is the rapidity with which the coloring matter fades in the penetrating sunlight which often strikes it in both summer and winter.

An indicator, which is used at switches, towers, and interlocking points, and is usually in series with the indicator line-

wire, is shown in Fig. 131. It is in reality a miniature modification of the disk signal mechanism, and consists of an armature, C, pivoted at G, to which is attached a small red disk or banner, D; this armature moving between the polar extensions, B, of an electromagnet, A. D is counterbalanced by an adjustable nut, E, so that the energy required to move the armature will be at a minimum. Insulated from but fastened to the magnetic yoke are the binding posts, F, to which the external circuit is connected. The moving system is of such design that the air-gap remains practically constant, while its sectional area continually increases

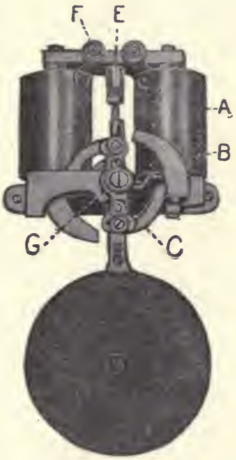


Fig. 131

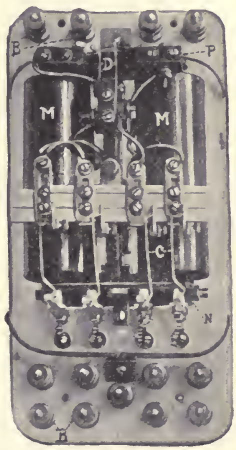


Fig. 132

with upward movement of the disk, the ampere-turns required being therefore very low. A slight amount of rust will prevent movement of the armature, hence the indicator is enclosed in a sealed housing having a glass aperture before which the banner moves.

One type of polarized relay is illustrated in Fig. 132. Upon a porcelain or slate base the magnet coils, M, with their cores and supports are mounted, with the armatures, P and N, the former polarized or permanently magnetic, the latter neutral. D, D, are the polar contacts; and C, C, the neutral front and back contacts, and fingers. Binding posts, B and B', are for the external connection of these coils and contacts.

In Fig. 133 an interlocking relay is shown, in section and elevation. This in reality consists of two relays, whose armatures, A and A', are dependent upon one another. This is effected by the locking dogs, D, whose points, P, engage with the ends, E, on the armatures, by the action of the rollers, R. When current ceases to pass through the magnet coils, the armature falls (if not locked) and its roller forces over the dog, thereby preventing the other armature from dropping. Each

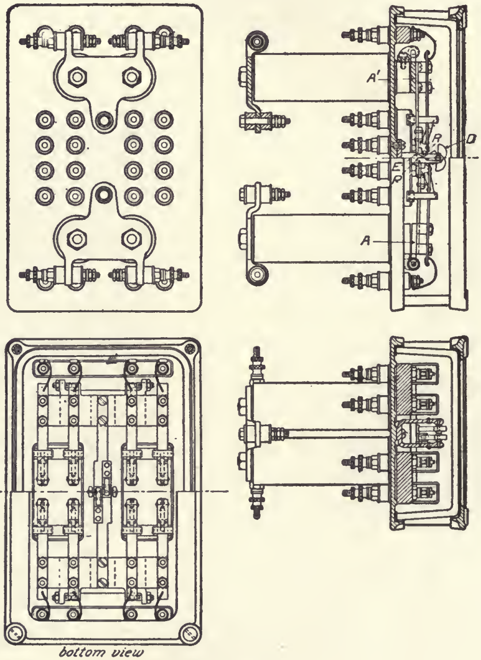


FIG. 133

relay has four sets of front and back contacts, the construction being similar in many respects to those herein described.

Fig. 134 shows a glass-enclosed, also a glass-mounted, neutral relay, with four front and four back contacts. Such relays are generally employed as track instruments, and are wound to a comparatively low resistance.

The principle of the type, D, structure is illustrated in Fig. 135. G is the main gear, which, driven by a motor, in turn produces the reciprocation necessary to clear the semaphore,

through the lever, *J*. Both *J* and *G* have the shaft, *A*, as a center, *J* being loose thereon. *M* is the slot magnet, whose armature

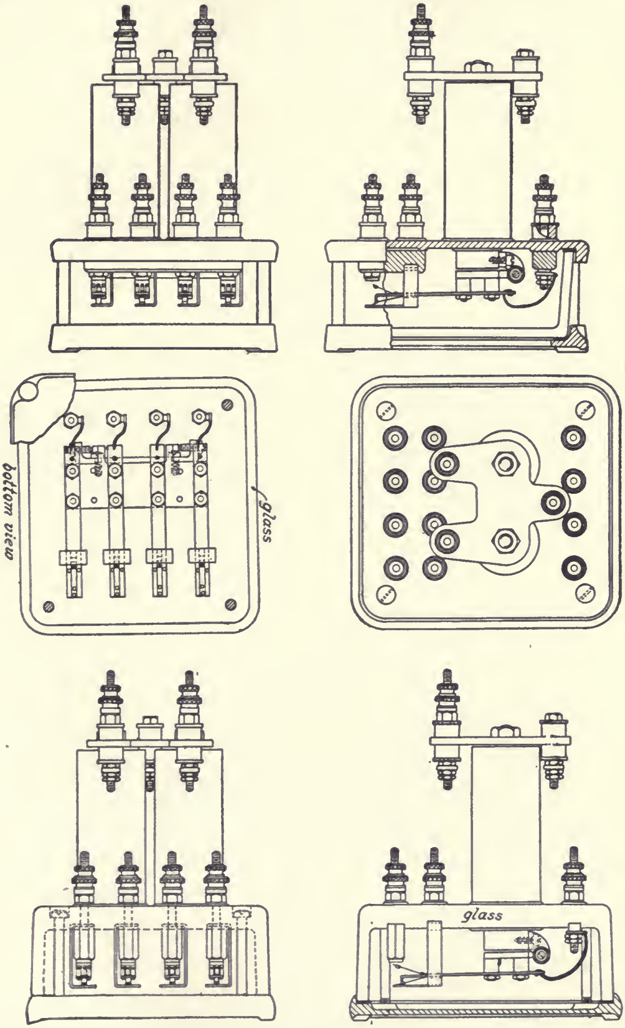


Fig. 134

is secured on and gives motion to the pivoted bar, *F*. *H* is a pivot bearing for the end of the rod, *B*, and *R* is a roller stud on the same. *D* is a trigger-shaped piece fastened to *G*, which engages with the end, *E*. If *M* be deënergized, and *G* rotated

in the direction of the arrow by the motor, when *D* strikes *E*, *R* will force *F* up, and cause *D* to pass *E*, thus imparting no motion to *J* or the semaphore, a stop, *S*, preventing *F* from being thrown too far. If *M* be energized, *G* evidently, by a converse reasoning, will cause *J* to move in the direction of

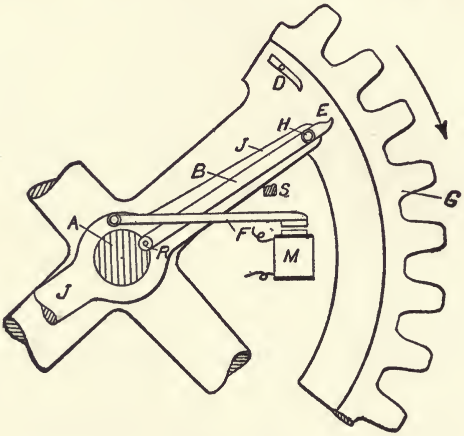


Fig. 135

the gear, and clear the semaphore. The requisite changes in interconnection and disengagement are also effected by the moving system, but these need not be entered into.

A type, *F*, motor mechanism for a double semaphore structure is shown in Fig. 136, and is similar in mechanical design to the electro-gas arrangement. Two independent sets of mechanism are used, but only one will be described. The motor, 15, frame 5, dashpot pistons, and clutch magnets are supported by the iron base, 8, as are also the side frames, 6 and 7, which act as housings for the gear shafts, 36 and 37, and retain the clutch levers, 11 and 12 (which are hidden from view). Rigidly secured to the dashpot cylinder, 29, is the thrust rod, 13, the dashpot pistons being mounted on pedestals within the frame and on the base, 8. This thrust rod is guided by the cylinder, 29, the upper end of 13 passing through a bearing in frame 5. The semaphore, connected to 24 by a link, is held at clear by a latch engaging with a lug on the clearing lever, 22. The thrust rod, 13, carries the latch support, 96, which in turn carries clearing lever

22, thrust piece 100, and a latch engaging with the lug on 1, to hold the semaphore at clear. 100 carries a V-shaped latch, 33, which engages with the lug on the clearing lever, 22, the clearing operation being indirectly performed by the train of motor-driven gears, 3.

The movable contacts of the circuit controller, 21, are operated

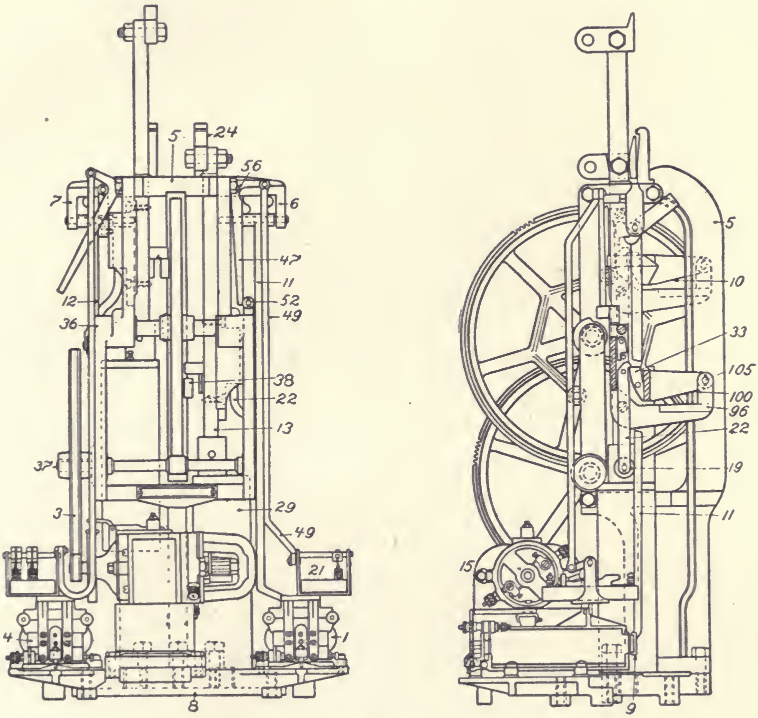


FIG. 136

by the control rod, 49, and escapement lever, 47; the latter is thrown by the latch support roller, 52. The front armatures of the clutch magnets, 1 (one magnet being on each side), control the parallel contacts of the motor circuit, while the back armatures are secured to the clutch levers, 11, thus keeping the latter under the control of the magnets. When the home blade is at stop, the controller contacts for the series motor, 15, are closed, and the distant clutch magnets are on open

circuit, so that the latter cannot be cleared before the home is fully at clear. The motor circuit is closed directly the home clutch magnet is energized, by the front contacts, 4; while simultaneously the rear armature, 9, is attracted, thus preventing the clutch lever, 11, from moving when the stud roller exerts its pressure. The motor now drives the gears and brings 38 under 100, forcing it up. As 11 is securely held by 9, 22 cannot swing back; hence the thrust rod and all its appurtenances are carried to the clear position, in moving to which roller, 19, pivoted in 22, rolls against 11. The final portion of this movement to clear brings roller 52 against the short link of escapement, 47, rocking it about 56, so that rod 49 operates the circuit controller and opens the motor circuit, at the same time closing that of the distant. The home is held at clear by the action of the lug on 11, which engages with a latch on 96, releasing the downward pressure on the stud roller, and allowing the distant to be cleared by the motor. A stud roller similar to 38 is on the opposite side of the gear and displaced 180° from 38; for clearing the other blade, a similar structure to 96–100–52–, etc., is employed.

After having been cleared, 38 moves beneath 100, the signal circuit being broken as soon as the clutch magnet is energized, as before. The motor circuit is opened by the front armature, and the rear armature allows 11 to swing back sufficiently to permit the retaining latch to disengage and cause the return to danger by gravity, this movement being dampened by the dashpot, 29. As soon as this movement begins, the circuit controllers, 21, are reversed, and should the motor inadvertently become on closed circuit the gears will merely revolve uselessly, since 38; cannot clear the semaphores unless clutch magnets, 1, are energized. Should the clutch magnets become deënergized with the blades partly at clear, 22 would swing back, since latch 33 is permitted to pass the clearing lever lug, thereby throwing the semaphore to danger, as 100 swings on its pivot 105 to the normal position after the stud roller has moved beneath it.

A double electromechanical slot is shown in elevation and section in Fig. 137. The dashpot shells, *D*, are secured to the rods, *R*, which are interposed in the semaphore links. When *B* is forced upward by the operator's lever, *L* will tend to swing

outward on its pivot. If the enclosed coil magnet, M, be energized, its armature, A, will hold C at the inner position, so that L cannot move, and motion of B is transmitted to R. If, however, M be deënergized, roller O throws C over, in opposition

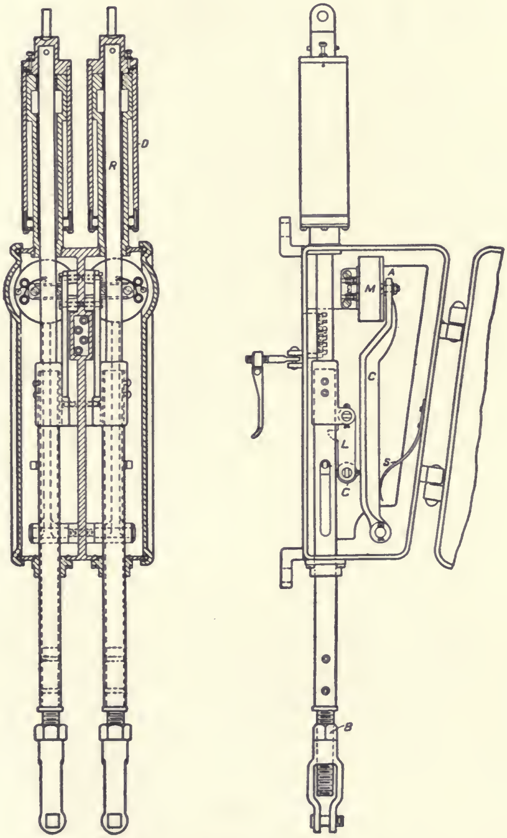


Fig. 137

to the spring S, and B moves upward without throwing the semaphore.

In Fig. 138, which illustrates a combined tower indicator and bell, S is a miniature semaphore showing the condition of a track section or signal, which is thrown by the armature, A, of the magnet, M, through the bell crank, L. When S moves to dan-

ger, the clapper *C*, on the semaphore rock-shaft strikes a gong, *G*, thus warning the signal operator. The armature also carries front and back contacts *T* for introduction in the circuits of the tower.

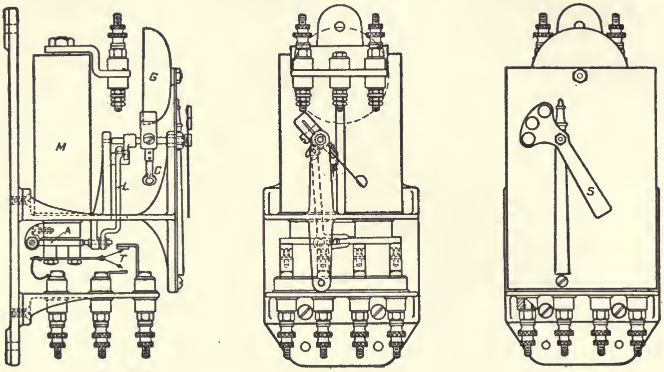


Fig. 138

Fig. 139 outlines a switch instrument which does not close the circuit contacts (on a normal danger network) until the rail point has reached its fully normal position. These contacts, *C*, are actuated by the links, *L*, arranged about the rock shaft, *R*. When the sector, *S*, is moved in the direction of the arrow, the

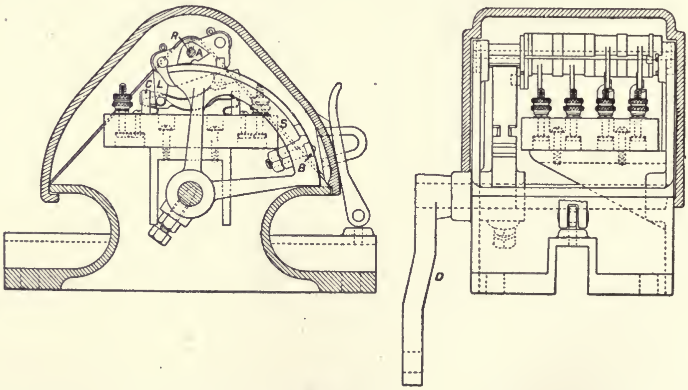


Fig. 139

steel block, *B*, engages with the piece, *A*, and thus opens the contacts. The switch link is fastened to *D*.

A standard switch indicator is shown in Fig. 140, the miniature semaphore being moved in a somewhat similar manner to that

shown in Fig. 138. Front and back contacts are also provided, a push button, *P*, being introduced in series with the magnet winding, and in shunt with the front "stick" contact. With

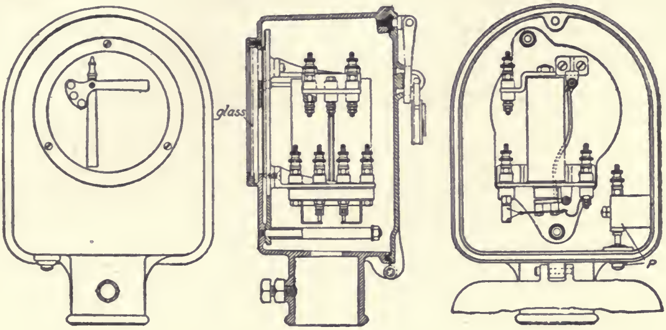


Fig. 140

this device, a trainman, by pressing the button, may ascertain the condition of the two preceding blocks, the semaphore being normally in the danger position.

In Fig. 141 the standard wireless connections for single-track

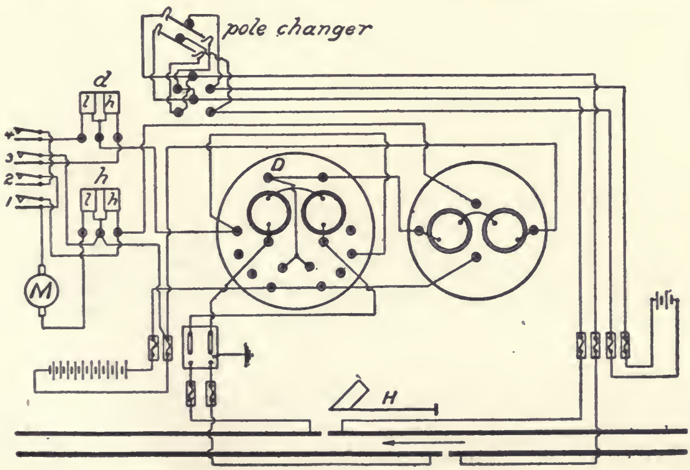


Fig. 141

one-way movements with overlap appear. The motor, *M*, is in series with the front-contact of a slow-releasing relay in series with the track relay, *D*, front contact, the contacts, 1, 2, 3, 4 being operated simultaneously by movement of *H*.

In Fig. 142 the wireless connections of a normal clear home and distant signal, *S*, for one of the tracks of a double-track road, and a polarized relay, *P*, are shown. The scheme of interconnection is an elaboration of that already given in Fig. 70, utilizing a compound slot, *h*, in series with the motor for the home blade and a simple wound slow-releasing slot, *d*, for the distant. This is the usual practice, as the home is cleared first, and the effect

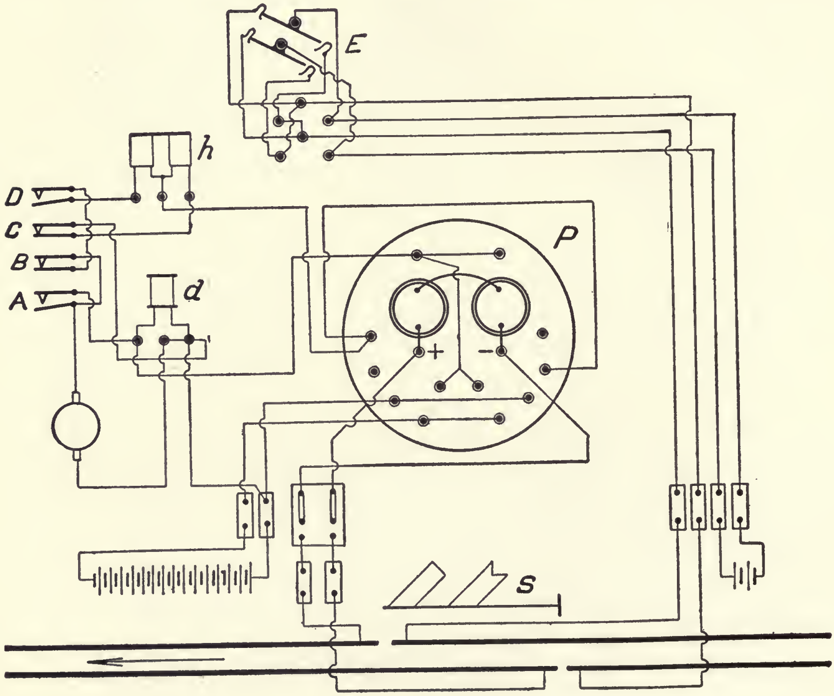


FIG. 142

of drop in potential is not so manifest in the case of the distant slot. *E* is a polarity reverser, for the control of the preceding distant.

Fig. 142*a* shows the standard connections for a normal clear home and distant disk-signal on one of the tracks of a double-track road, *H* being the home banjo. This arrangement is an extension of the home banjo-circuit given in the preceding chapter, a polarized relay being used, as in the latter case.

T has two components, which are connected in series. When one of the neutral armatures comes in contact with the back contact point (by short-circuiting of the track) but one cell is connected to the latter. *N* operates both blades, being under rather heavy discharge when the low-resistance winding is in circuit and the disk being cleared, and under slight demand when at clear. The insulating joints are not shown opposite,

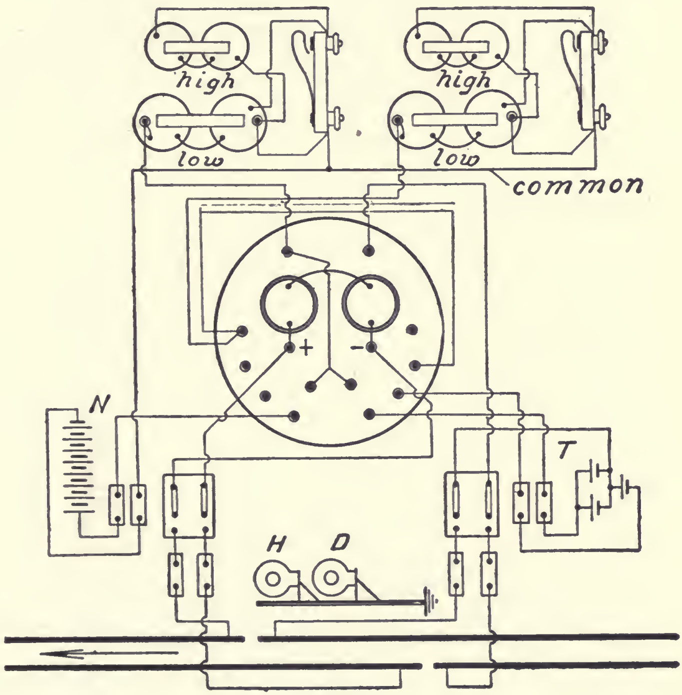


FIG. 142*a*

as in practice they are staggered, in common with the ordinary joints.

Figs. 143 and 143*a* are consecutive circuits showing the Hewett line-wire scheme of normal danger operation, with a normally open track-circuit, the track relays being normally closed for switch indicator control. At signal 522, the track element is connected in series with the opposed or differential relays or windings *A* and *B* (having a common armature), but in this case

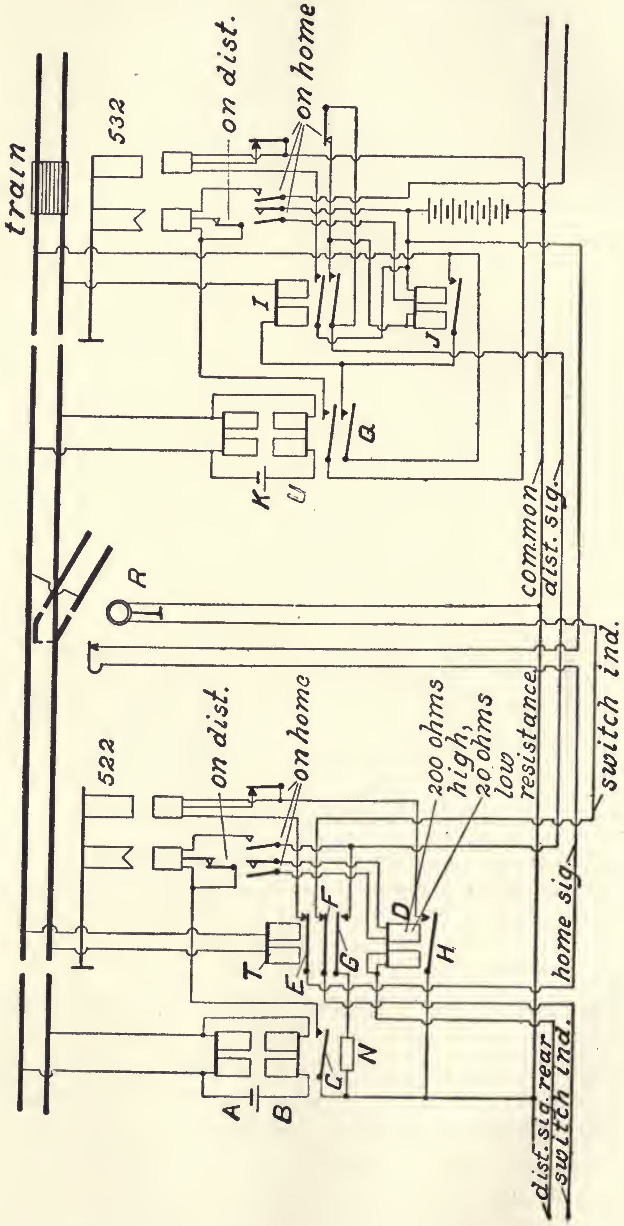

train
532
on dist.
on home
I
J
Q
K
U
R
common
dist. sig.
switch ind.
522
on dist.
on home
200 ohms high,
20 ohms low
resistance
D
H
F
G
E
T
N
C
A
B
home sig.
dist. sig. rear
switch ind.

FIG. 143

no energization results, so contact C is open. When A (which is in shunt with the track) is short-circuited by a train or otherwise

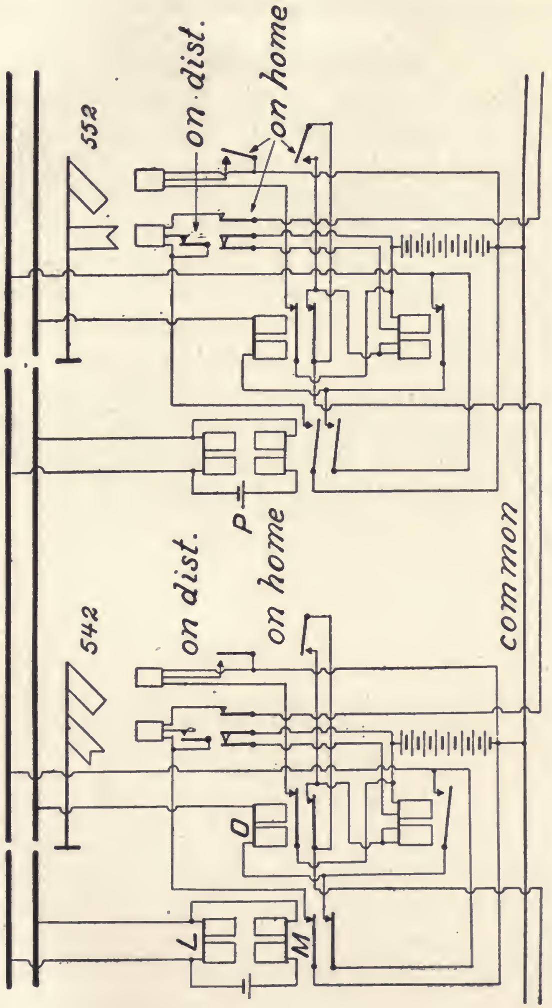


FIG. 143a

B is fully energized, and consequently, C is raised; T receives current from K, and is in series with a differential winding, U.

At 532, a train appears in the home block, which short-circuits the upper winding, L, and fully energizes M; thus raising both

contact points, and clearing 542. The 4-ohm relay, *O*, is also energized (by the closing of the lower contact of *M*) from *P*. The home mechanism, when cleared, closes two contacts and opens one; when moving to stop, the reverse; *D* is a relay having two connections of its windings: one of 200 ohms, the high resistance, and the other of 20 ohms, this being effected by a shunting contact operated by the home mechanism. Also, when either the home or distant clears, short-circuiting contacts are operated, which throw into circuit the high-resistance slot or retaining coil, which maintains the clear position of the semaphores, with insignificant current consumption.

When the armature contact, *Q*, is closed, *I* is connected to the track; and, if energized, the local home will clear, and subsequently, the distant. At 522, *N* is a resistance in series with the distant signal line through *G*, which is the cause of a supplemental energization of *J*, having a subsidiary control over *I*. The indicator, *R*, is connected to the indicator line and common, and is in series with *F*. The home semaphore at 522 is controlled by *E*, and at 532 by a front contact of *I*.

CHAPTER XI.

UNION APPARATUS.

IN Fig. 144 the track and motor connections embodied in the Union standard normal clear polarized rail-circuit scheme of operation are shown. The home signal, *H*, protects the block immediately behind it (not shown), the approaching train in

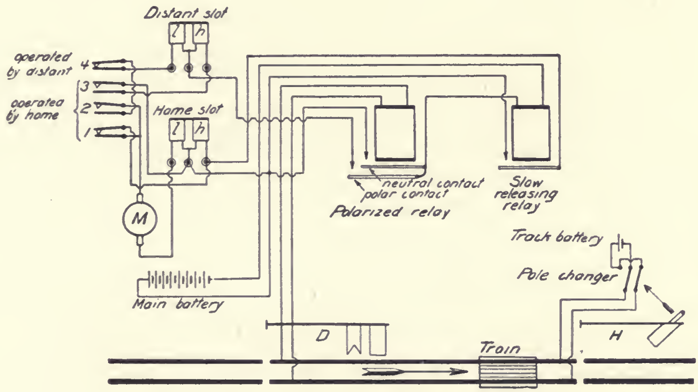


FIG. 144

the block preceding short-circuiting the track section and holding the signal at *D* at stop, in a manner now to be described. Excepting the track battery and pole changer at *H*, the entire arrangement of accessories and connections shown in the figure is at *D*. *H* has the same subsidiary devices, but their delineation would over-complicate the diagram.

The track battery at *H* is not connected directly to the track, a pole changer being introduced. The polarized relay is connected at the other end of the block (relay control being interposed where the blocks are of excessive length) and is affected

by three conditions: (1) the cessation or continuance of current, irrespective of its polarity; (2) the establishing of current of one polarity; and (3) establishing of current of the opposite polarity. Under certain conditions it would be apparent that the polar contact would still remain closed upon cessation of current, when the latter was in the proper direction. To provide against such a contingency, a supplemental break is introduced, as will be apparent later.

The polarized relay has two armatures, a neutral and a polar; the former being raised whenever current circulates around the coils; and the latter closing its contact when the current is in one direction and opening it when a reverse polarity is set up. The neutral contact controls the home semaphore, and the polar contact the distant semaphore in every case. When a train occupies the block (as is the case for the signal at *D*, or by reason of an open switch or similar cause), the polarized relay is de-energized; the home signal assuming the danger position, by the action of gravity. This movement to stop operates the pole changer, and thereby throws the distant signal in the rear to the caution position, through the action of the polar contact, distant slot, and gravity.

The reversal of polarity must evidently cause a momentary drop of the neutral armature, due to the instantaneous cessation of current through the magnet coils, followed immediately by a sweeping out of the residual flux. As the contact of this armature is in the home slot and motor circuits, it follows that the signal arm must move to danger. However, an intermediate slow-releasing relay contact is in series with the motor and home slot, the magnets of this relay being in series with the neutral armature contact and having a very high self-induction, being also provided with a copper tube for choking effect, so that before the self-induction current occasioned on breaking the circuit can neutralize itself (and consequently the residual flux cease) the circuit is again completed, and its magnetism fully restored; the home signal arm being thus unaffected.

The slot magnets are compound wound, having two separate windings, the inner of many turns and high resistance and the outer of few turns and low resistance. The high-resistance coils are connected in multiple with the main battery,

and the low-resistance coils in series with the motor; so that when a heavy current passes through the motor it must produce a corresponding increase in the magnetic effect upon the slot magnet armatures.

The sets of contacts, 1, 2, and 3, are indirectly operated by movement of the home semaphore; and 4 by the distant. Both 2 and 3 are normally closed (when the signal is at clear), while 1 is normally open (shown closed in the figure, since the signal is at stop). When the distant arm is at clear, 4 is opened; when at caution, closed, as in the diagram. The high-resistance home slot winding is connected across the battery through the contact of the slow-releasing relay; the same winding of the distant slot being in multiple with the battery, through the polar and neutral contacts of the polarized relay on one side, and through the home operated contacts 3 on the other side.

The motor is connected to the battery for the movement of the home blade through the low-resistance winding of the home slot, normally open contacts 1, and the slow-releasing relay armature; and for movement of the distant semaphore through the normally closed contacts 2, normally open contacts 4, low-resistance winding of the distant slot, and the polar and neutral contacts of the polarized relay.

A partial elevation and section of one type of such a signal mechanism for semaphores is shown in Fig. 145. The motor, 17, through its armature shaft, 39, drives the large gear, 21, whose pinion, 22, engages with the sprocket-carrying, gear 20. The home semaphore is connected to the rod, 7, pivoted at 33, and the distant to 8; the former being at clear. Motion is imparted to these rods by the movable members, 37, which rock about a shaft, 32. These members carry the slot magnets 9 and 34, to which connection is made through flexible cable, to the binding posts, 36. The armatures, 40, of these magnets, through the latch ends, 31, engage with the train of links, 30, 25, 29, and 28, so that when 34 is energized under specific conditions, the cam piece, 28, is immovable.

To the ends of the arms, 37, are pivoted two links, 6 and 10. The former operates the plunger, 4, of a dashpot, the shell, 3, of which is held in the mechanism frame. The relative retardation is varied by the screw, 2, which governs the discharge of

the entrained air through the orifice, 1. These dashpots prevent spasmodic movements of the mechanism when returning to the stop position by gravity. Link 10 operates a current reverser or pole changer, the essential parts of which are the sets of contact springs, 14 and 13, with the scraping pieces, 12. Connection to the track circuit is effected through the binding posts, 11, 15, and 42.

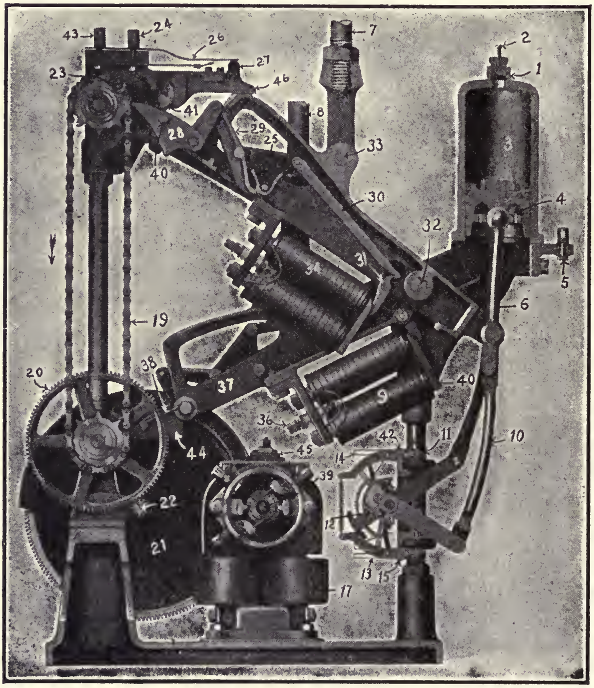


Fig. 145

As only the home blade is at the clear position, the distant block must be occupied or dangerous. If it be supposed to be again clear, 9 will be energized simultaneously with the passing of the current through the motor. As the motor gains speed, the chain starts to move, and as 44 is held rigid by the interposed links and the spring, 38, 37 will be carried upward by the action of the roller engaging with 44. When it reaches its extreme upward position, a stud opposes gravity through

the latch, 41, latching taking place when 40 passes the hook. At the same time, the motor circuit is opened at contact springs, 26, by the insulated strip, 27, through the pivoted piece, 46, which 37 strikes, since 43 and 24 are in series with the motor. The brake, 45, is applied when the current through the motor ceases, thus bringing the armature to an almost immediate stop. The electrical connections have been described in connection with the preceding figure, the external and interconnections being made at the posts, 5.

In Fig. 146 the arrangement, which is frequently used to clear the signal arm, is isolated. The motor drives the chain, *J*, in the direction of the arrows. This causes a roller, *R*, to strike the pivoted member, *E*, which is connected to the links, *F* and *G*. The semaphore rod is pivoted at *A*, and the whole

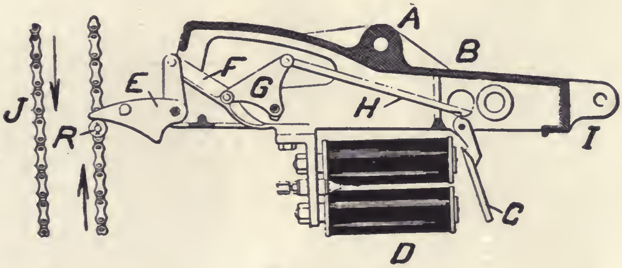


Fig. 146

structure at *B*, the dashpot plunger and polarity changer being operated from end *I*. If the slot magnet, *D*, be energized, armature *C*, through its hook end, will prevent *H* from moving when *E* is struck, through the action of *F* and *G*. Hence *R* raises *E* and the entire arm about *B* as a center, thus clearing the semaphore in opposition to gravity. If *D* is not energized, this cannot occur; and if it be de-energized when the blade is at clear, the release of *H* will cause it to fall to stop.

The Union standard disk mechanism is illustrated in Fig. 147. It consists of an aluminum disk or colored banner, *D*, carrying a lens at its center; and suspended upon a rod, which passes through the pivoted armature, *A*, of the electromagnet, *M*. The moving system is counterweighted at *W*, the electromagnet being held within a box fastened to the rear of the narrow case, a front view of which is shown at *C*. A hinged

lamp is placed in the rear of C for night signaling, the rays of this lamp passing through a lens at the center of the disk. The rear of the aperture, P, before which the banner moves, is painted white, so that when the latter is raised a clear indication is given, the lower end only being visible, the clear lens before the lamp being also seen at the center of P. An opening is provided so that repairs and connections can be readily made.

In Fig. 148 a slow releasing relay is shown, A being the armature, B the back contact prong, and F the front contact. The magnets are wound to such a resistance that a high self-induction results at the current strength normally passing

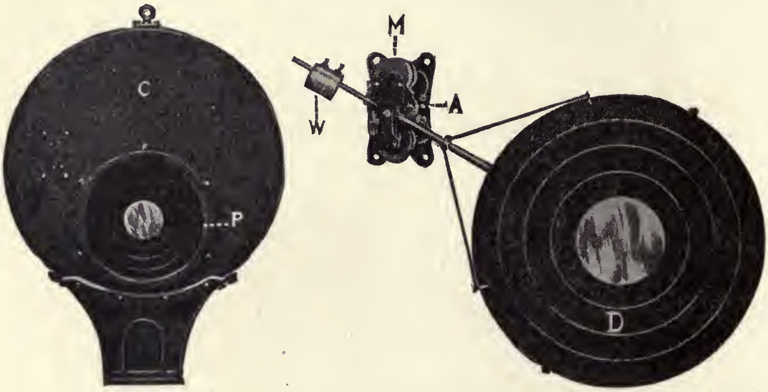


Fig. 147

through the coils. The magnetic circuit is long and of generous sectional area, the pole tips presenting a large surface to the armature. A soft copper sleeve is slipped over each core before the winding is put on. The eddy currents set up momentarily in the sleeve when any change in exciting current occurs, oppose any change in flux, and thus tend to retain the magnetism. These factors, combined with a short lift, small air gap, large percentage of residual magnetism, and high working flux density (much greater than is actually required for the mechanical work done) produce a slow release of the armature when the energizing current is interrupted. Such a relay is used in connection with the polarized wireless system, when slow-releasing slots are not employed, to prevent open-circuiting

of the home slot circuit when a momentary reversal of polarity occurs at the polarized relay.

Fig. 149 illustrates a vertical rotary switch-circuit controller in section. This instrument is intended to short-circuit the track relay at a track switch when the latter is open, or to short-circuit the signal relay. When the switch is closed, the contacts are open, so that the electrical conditions of the section are not interfered with. The arrangement consists of the dust and waterproof cast iron housing, *A*, provided with a

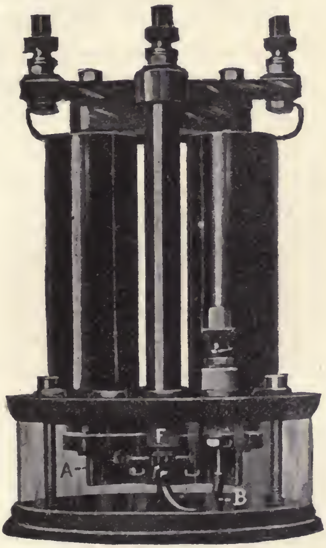


Fig. 148

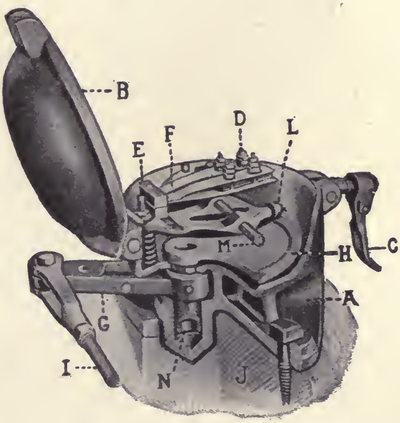


Fig. 149

hinged cover, *B*, which is held securely in place when closed by a lock and clasp, *C*. Fastened to an insulating strip are the phosphor-bronze platinum-tipped strips, *F*, with the binding nuts, *D*, for connection to the external circuits. The housing is fastened to the long tie, *J*, by lag screws, adjacent to the switch-point rail. It is connected to the latter by the rod, *I*, which imparts motion to the crank, *G*, fastened to the cam piece, *H*, the pivot being the shaft, *N*. Riding on the inclined flat lip, *H*, is a small roller, *L*, fastened to a cast iron rocking piece pivoted to the shaft, *M*, *L* being pressed against *H* by the action of the spring, *O*.

Closing the switch will, through the rod, *I*, produce a movement of the rotary cam piece and thus throw the roller, *L*, upward, which compresses the spring, *O*, and moves the lower insulating strip downward, allowing the contact strips, *F*, to separate, thus breaking the circuit. With *G* in the position shown in the figure, the switch is open, the contact strips thus short-circuiting the track. The purpose of the rotary cam is to absorb the motion given to *G* by every car wheel which passes over the switch-point rail, and prevent its being communicated to the contact strips. In Fig. 150 the mode of application of such a box to a switch is shown. *K* is the switch-point rail, which is connected to the box crank by the rod, *I*.

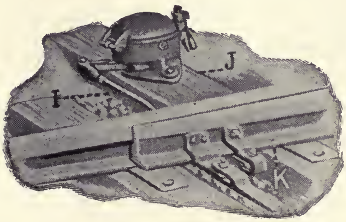


Fig. 150

In Fig. 151 a duplex rotary circuit-controller is illustrated.

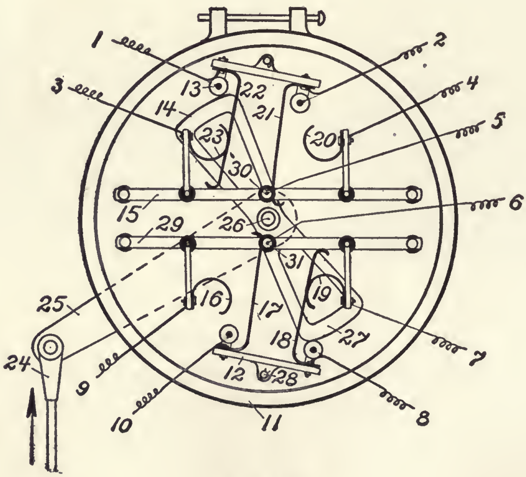


Fig. 151

This arrangement is intended to control from one to four separate circuits; or it may be employed to reverse the polarity or connections of two independent circuits. It is frequently employed in place of the switch circuit-controller above described. The instrument consists (Fig. 151*a*) of two operating cams, *V*,

whose outer edges bear against rollers arranged on pivoted bars, the latter carrying contact springs and connectors, X.

Within the weatherproof cast iron housing, 11 (this being merely a connection plan), are two cams, 14 and 27, arranged to move about a pivot, 26. These cams are secured to the crank, 25, operated by the switch, semaphore, or interlocking machine rod, 24. The outer edges of the cams bear against small rollers, 13, secured to the rocking members, 12, pivoted at 28. These rocking members carry the insulated contact springs, 21, 22, 17, and 18.

FIG. 151a

The stationary pieces, 15 and 29, also carry insulated contact spring strips, 16, 19, 20, and 23, which are in or out of contact with the movable strips according to the position of the cams, and consequently the position of 24. Connecting posts, 30 and 31, to which the wires, 5 and 6 pass, are insulated and stationary, and have a projection beneath which obstructs the motion of the movable contact springs. In the position of the cams shown, 21 is in contact with 30, and 31 with 17.

To show the use of the arrangement as a reverser of polarity, suppose that a track battery is connected to 1 and 2, one track rail being connected to 3 and 4. If the other rail is connected to 5, it is evident that the polarity of the track circuit is reversed at every consecutive movement of 24; which may be secured to the home semaphore of a signal on the wireless or polarized track-circuit system. By connecting one side of one circuit to 1 and 3, and the other side to 7 and 8, we have double-pole simultaneous control of two circuits. Numerous such combinations will occur to the signalman.

Fig. 152 shows a polarized indicator mechanism, such as

is used at a siding or crossover, or to indicate the state of two or more distant devices having suitable battery connections. When applied at a siding switch, it apprises the brakeman of an approaching train, and the movement of the home signal governing the section in which the switch is located. When used in conjunction with a slotted mechanical signal, it may similarly indicate the approach of a train, and the clearing or return of the semaphore.

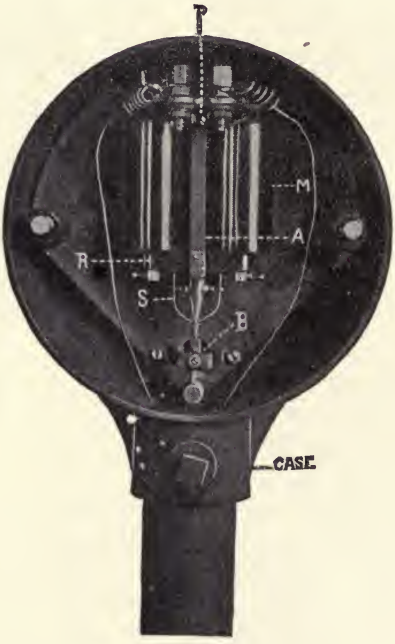


Fig. 152

It consists of an electromagnet, *M*, whose permanently magnetized armature, *A*, is held centrally in a state of static equilibrium by the adjustable springs, *S*, between the pole pieces, *R*. This armature is pivoted at *P*, and engages at its lower end with a rocking member, *B*, the latter giving motion to a pointer (not shown) which has three positions of rest, according to the direction of the current or its continuity. The mechanism is enclosed in a cast iron box, placed at the top of an upright located near the switch.

Fig. 153 shows a front and side elevation of a multiple unit semaphore indicator, with the binding posts and armature contacts. This type has three front contacts, 1, 2, and 3, also two back contacts, 4 and 5. The electromagnet, 8, through the armature, 11, operates a shaft, 7, which is secured to a miniature semaphore moving before the face glass, 9. Interconnection and connection to external circuits is effected at the binding posts, 10. These instruments are mounted in a moisture-proof

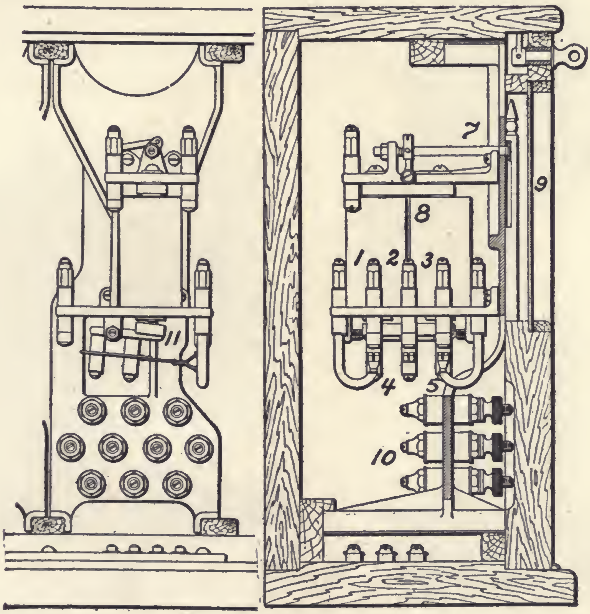


Fig. 153

housing in gangs or banks, and find application in train sheds, signal towers, and stations. Frequently single-stroke and vibrating bells supplement these devices, giving an audible announcement of the semaphore movement. A common bell for each bank may be used, but it is better practice to employ individual bells.

Fig. 154 illustrates a neutral type disk indicator, which is applied where it is desired that two indications be given, as, for example, to indicate the condition of a given block, whether occupied or clear. It consists of a metal disk, *D* (usually red),

which is actuated by the armature of the electromagnet, *M*, the latter being in series with a track-relay armature contact. *D* is fastened upon the vertical shaft, *S*, which is fastened by a link and stud, *P*, to an extension, *E*, of the armature. When *M* is energized, *E* moves outward a trifle, thus permitting *P* to swing around, and present the edge of the disk to the observer. *B* is of non-magnetic material, the armature being partly enclosed by it.

Fig. 154

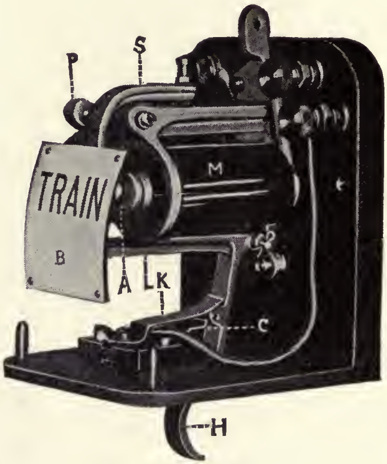


Fig. 155

To apprise a tower attendant of the presence of a train in a certain block, or indicate the approach of a train to a signal, a drop annunciator is used. This consists, as shown in Fig. 155, of a banner, *B*, with the desired inscription on its face, which moves before a glass-covered aperture in the housing (shown removed). This banner is affixed to a pivoted casting, *L*, which is provided with a handle or finger, *H*, and is held in its upward position by a trip upon the piece, *S*, pivoted at *P*, whose position and movement are adjustable. To the latter, the armature, *A*, of the electromagnet, *M*, is fastened. When a current passes

through M, B is released in an obvious manner, and is restored by means of the handle, H. An auxiliary circuit for audible announcement of the movement of B is sometimes made use of, and consists of a battery and bell in series with the contacts, K–C, the latter being closed when L is in its lower position.

Drop annunciators are used in connection with crossing circuits (see Fig. 31) to announce approaching trains, and at interlocking towers to avoid delays caused by switching engines drilling within yard limits. Delays to through passenger trains by long, slow-moving freight trains, which receive a signal prior to the former, are prevented by its use, so that the operator can first give the passenger train the right of way.

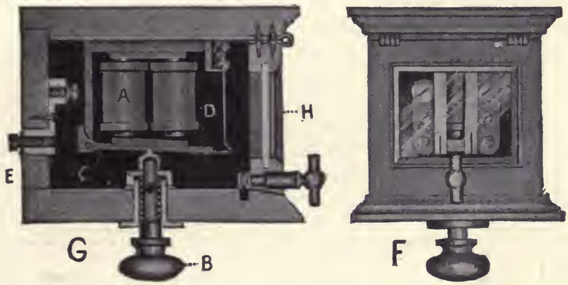


Fig. 156

One form of circuit controller, the application of which was considered in Fig. 77, is illustrated in Fig. 156, G being a part section and elevation, and F a front view. The electromagnet, A, enclosed in a box having a glass door, H, is in series with the armature contacts, D–C, connection to external circuits being afforded by the lugs, E. When the knob, B, is raised, these contacts are closed, hence a current passes around A (providing the external circuit is otherwise complete) thus raising the armature, C, and maintaining the energization of A. Should the external circuit be opened, C will fall, and A will be deënergized, until C is again raised by the operator, irrespective of the condition of the external circuit.

CHAPTER XII.

ELECTRO-PNEUMATIC AND ELECTRO-GAS SYSTEMS.

ELECTRO-PNEUMATIC systems, which are used on many busy lines, employ low voltage controlling circuits, the working medium for operating switches and semaphores being compressed air, supplied by a local compression plant and conveyed to the subsidiary apparatus through underground pipes. The circuits generally used on such systems (normal clear for single track) are shown in Fig. 157.

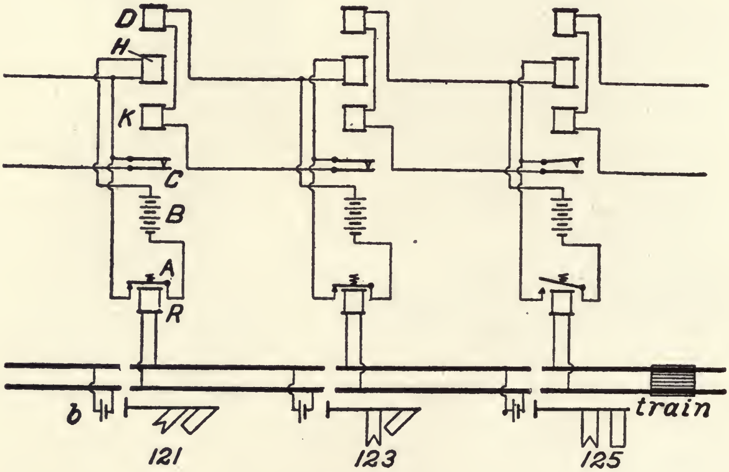


FIG. 157

Three consecutive home and distant signals, 121, 123, and 125, are considered, with single sections, a train being on the block protected by 125. The admission of air to the cylinder operating the home semaphore is controlled by the electro-magnet, *H*, and to the distant cylinder by *D*. A circuit controller, *C*, is operated by the home semaphore's movement, and is closed when the latter is at clear; while *K* is a circuit breaking

arrangement in series with the distant magnet, and operated by the returning to the stop position of the home arm, thereby preventing a clear distant arm when the home is at danger, an occurrence which would be confusing to the engineman. Each section is provided with a track battery, *b*, and relay, *R*, as in other systems. *B* is the main battery which operates the home and distant control magnets, the former through a local circuit, the latter over line wires.

The train, by short-circuiting the track relay, open-circuits the main battery, and, by depriving the home magnet of current, moves the home blade to the stop position. The distant also assumes the caution position by the action of the circuit breaker; the distant blade of 123 thus maintaining this position by reason of its opened circuit controller. Sometimes the latter is effected by using the polarized track-circuit principle, line wires not being then used.

Liquid carbon dioxide (CO_2) has numerous advantages as a source of power, which result from its enormous expansion at almost any pressure desired, through the use of proper valves. In exhausting at low pressure, or entering a chamber during expansion, it precipitates no moisture; in fact it may be relied upon to remove any moisture with which it comes in contact, since its point of saturation is high.

The Hall electro-gas signal, which uses this agent as a motive power, is now regarded as a very high development of the automatic semaphore, and possesses inherent features which bid fair to rank it as a standard type. It employs standard posts, case, and fittings, with additional special accessories for the control and reception of the gas and flasks. These flasks are identical with those used for soda fountain purposes, and are about four and one-half feet long and eight and one-half inches in diameter, weighing when charged about 150 pounds, containing 50 pounds of liquid gas. Two such flasks are used at each signal, and are placed in a chute near the base of the latter.

The flasks are provided with a safety valve blowing off at 2400 pounds pressure, and when charged exert a pressure of about 800 pounds per square inch. In direct sunlight, or when near a locomotive boiler, this valve operates, although the flasks will actually stand about one and one-half times this pressure.

Before passing to the operating cylinders, this is reduced to about 40 pounds by a reducing valve.

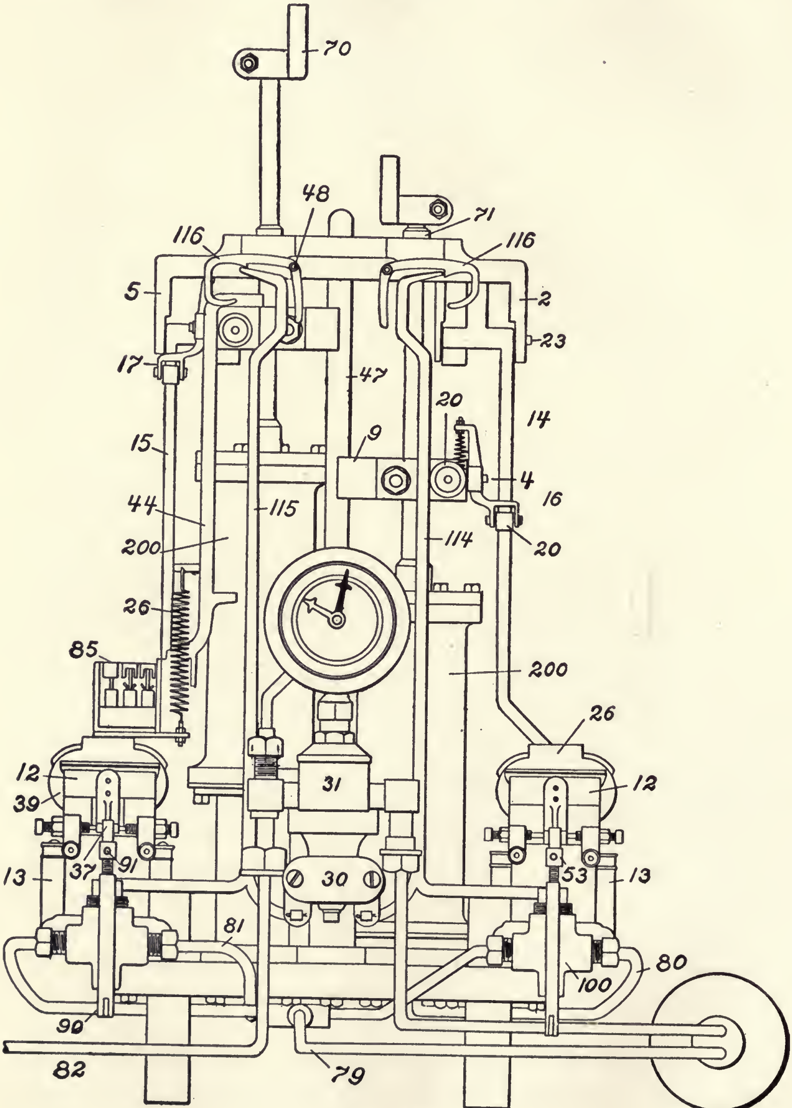


Fig. 158

In Figs. 158, 159, and 160, the mechanism of this signal is revealed. The first is a front elevation, the second a side view,

and the third a part section showing important details of construction. The signal is a home and distant, although a three-

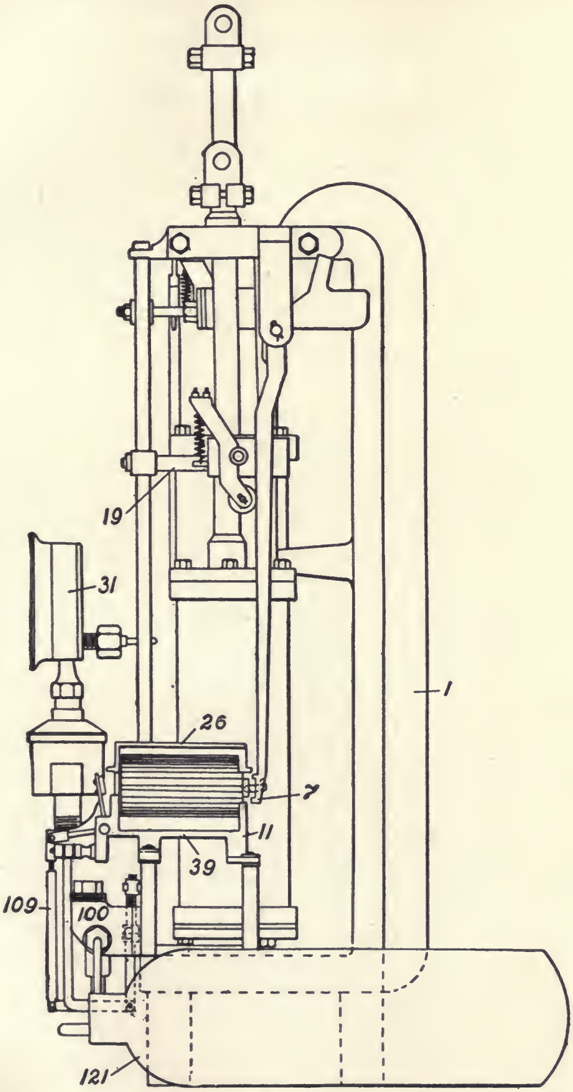


Fig. 159

position structure can be equally well adapted to this motive power. The gas expands and exerts its force through the verti-

cal cylinders, 200, the semaphores being moved by the extended cylinder rods, 70, the cylinders being movable, and the pistons

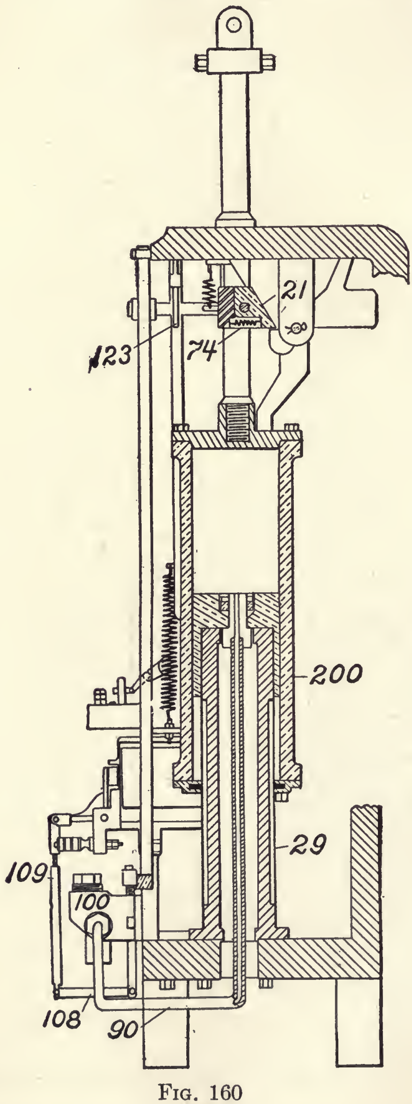


Fig. 160

fixed to the mechanism frame. The home signal-control electro-magnet appears on the right side and the distant on the left;

these magnets, through their armatures, governing the admission of gas to the working cylinders, and are interposed as a function between the cylinders and flasks.

The magnets are controlled by track circuits on either line wire or wireless systems, and are energized through a local battery. In connection with Fig. 162 such an arrangement will be described. When a blade has been cleared, it is held in the clear position by latches controlled by the magnets, their release allowing gravity to throw the same to the stop position. The home movement controls the distant as in other types, the means by which this is effected being shown later.

The reducing valve, 31, whose gauge has two pointers, showing the supply and working pressures, is connected to the expansion chamber and valves, 100, the latter being controlled by the magnets, the armatures, 12, raising the link, 109, and lever, 108. The reducing valve is also in connection with the supply flask through the pipe, 82. The semaphores are held at clear by the clutch levers, 14 and 15, which are actuated by their attached armatures, 7, moving before the poles of the magnets. When the signal is at clear, the rocking latch, 21, holds it in this position by engaging with the clutch lever. The roller buffer levers, 17 and 16, keep the clutch lever from striking the magnet poles when the signal returns to the danger position, and maintain the armature at a short distance from the pole tips when in this position, so that danger of freezing fast is eliminated. The magnets, it will be seen, are double functioned, their front armatures operating the gas valve, and rear armature holding the signal at clear.

When the signal has cleared, the cut-off levers, 114 and 115, act, and cut off the gas from the working cylinder, allowing it to exhaust at the same time, they being controlled through the pawls, 116, pivoted at 48. These pawls engage with the roller, 20, at the upper position, the gas thus being shut off by their mutual action, the stroke of the cylinder being varied by changing the point of release and clutch engagement. The clutch casting, 9, is fastened to the cylinder rod, rod 47 guiding it. The position of 9 can be changed, thus changing the stroke. A switch, 85, is operated by the rod, 44, when the stud, 19, is in engagement with it, and rocks about a central shaft which carries the contact blades.

The clearing action is as follows: When the magnets, 39, are energized, their armatures, 7 and 12, are attracted, the gas valve being thereby opened through the links, 37, 108, and 109. The supply valve, 96 (see Fig. 161), is raised, while the exhaust port is simultaneously closed. Gas enters the cylinder through the center of the piston, and raises the former, thus clearing the signal. When the latch, 21, has moved past the projecting finger of the clutch lever, 15, the pawl, 116, is raised by the roller, 20, the cut-off lever, 115, moving downward. The links, 109 and 108, are thereby forced down, thus closing the supply

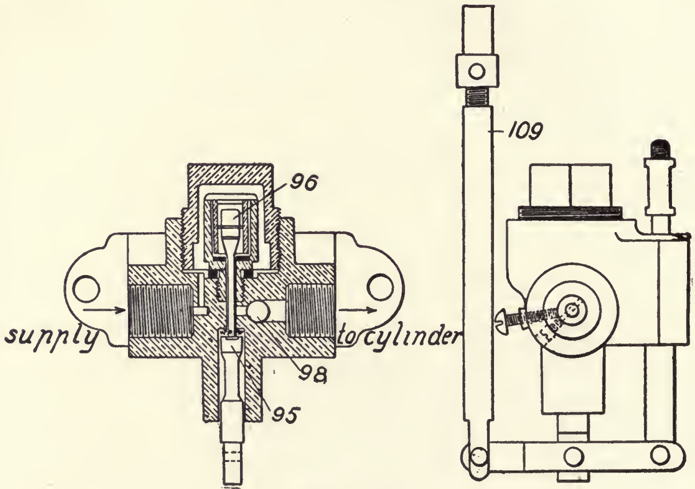


Fig. 161

port, 96, and opening the exhaust port, 95. The latch, 21, through its engaging with 15, thus opposes gravity, which tends to move the mechanism to danger. As long as the armature, 7, is attracted, the signal will remain at clear.

If the track section becomes occupied, armature 7 is released, thereby causing lever 15 to move back. This releases 21, and the semaphore moves to stop. A rapid downward movement is prevented, as the air must be forced out through the partly closed check valve, 98, the entrained air thus damping this motion.

The expansion chamber, 30, is for the purpose of allowing the gas to expand and increase its temperature. As an expanding

gas always lowers in temperature, extracting heat from the walls and adjacent parts, should freezing occur its particles are too finely divided to produce any untoward results. Freezing, however, by solidifying a gas having such great expansibility, is a wasteful process.

The piston area is five square inches, and with a 40-pound working pressure, the upward force is equivalent to 200 pounds, which gives sufficient margin for positive action. Should greater pressure be desirable, it can be changed by adjustment of the reducing valve. About 12,500 movements can be made per flask, with this working pressure, or 250 per pound of gas.

The magnets have two windings, which are connected in multiple when the valve is being operated, the high-resistance winding being used to hold the signal at clear. With the polarized track-circuit scheme, when slow releasing clutches are used, the second winding is first disconnected from the battery and immediately closed upon itself by a switch, the induction current thus set up (which opposes any change in flux) preventing the cores from being at once demagnetized and retaining the armature in position.

The slow-releasing clutch-magnets take a current of .0113 ampere at 4 volts, or .045 watt; and retain sufficient flux to hold the semaphore at clear for 2.5 seconds after they are disconnected from the battery, which gives ample time for polarity reversal, and full energization in the opposite direction. The valve requires .1 watt for its operation, and from four to six cells are used in the battery to which the magnets are connected.

In Fig. 162, *A*, *B*, and *C*, are the slot batteries respectively of the normal danger electro-gas single-blade signals, 1, 2, and 3. The cut sections, 5, 6, 7, and 8, have track relays of corresponding number, which produce the required interconnection. The battery, *B*, energizes the working magnets at 2 through the lower armature contacts of relays 7 and 6, and the upper armature contact of 5. Hence, when 7 is short-circuited, 2 will clear by the back contact of 7, providing the sections of 6 and 5 are unoccupied.

The actual circuits embodied in a normal clear, wireless, two-arm, home and distant electro-gas semaphore, for a single-track signal system, are shown in Fig. 163. *R* is a polarized

relay, whose neutral armature front contacts are connected to the main battery, *Q*, and both polar and neutral armatures to the home semaphore; *P* is a polarity reverser operating

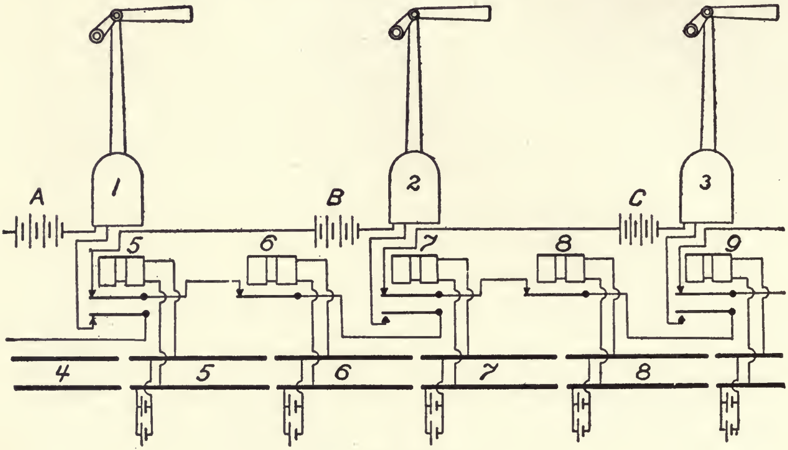


FIG. 162

the preceding distant polar armature; *N*, a compound wound and duplex armature magnet clearing (through its valve operat-

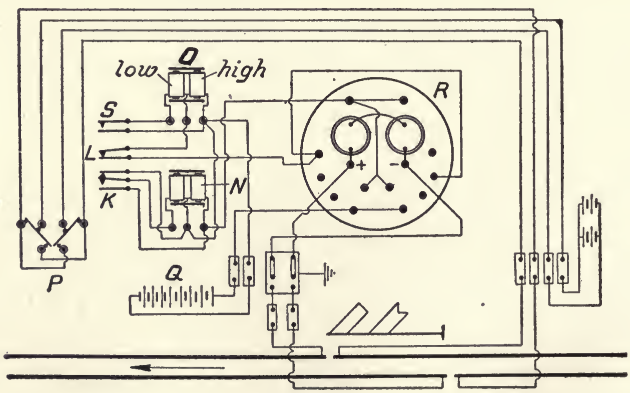


FIG. 163

ing armature) the home blade, and *O* the distant. Each has two windings: one of 280 ohms, and the other of 350 ohms.

These are connected in multiple when the semaphores are to

be cleared; the high resistance winding alone being used to hold it at clear. When the home blade is cleared, switch L is closed, thus giving current to the distant magnet from Q. K is a switch arm which is in contact with the upper finger when the home semaphore is at clear, and with the lower when at stop. Its function is to short-circuit the 280-ohm winding, thus leaving in circuit only the high resistance coils. Switch S connects the low resistance winding in shunt with the high resistance winding, it being open when the distant blade is clear, thus decreasing the watts used.

CHAPTER XIII.

ELECTRIC LOCKING.

An electric lock is a device, electrically controlled, which interposes a small latch or bar at a notch or recess in a movable or sliding piece, so that the latter cannot be given motion except under conditions governed by the lock. This moving piece obviously may be a semaphore, switch, or interlocking machine rod; in fact anything whose automatic control is desired.

Electric locking is sometimes introduced in mechanical levers, so that a signal operator cannot return to caution a clear distant that a train has just passed, then return the home to stop; permitting him thereafter to set up a false clear condition of a conflicting route by the mechanical unlocking that takes place. The lock circuit is through the rails of the section intervening between the home and distant signals, and in series with a battery and the lock magnets of the conflicting levers. The train may either complete the circuit directly or through the medium of a relay contact. Separate circuits may also be employed to lock the individual levers.

Electric locking, as a subsidiary function, is treated of in Chapter 5. It is scarcely possible to design a semi-automatic connection arrangement without the use of such locking; it forming the simplest scheme for controlling routes of any desired combination.

When a plate or rod connected to a lever has a notch or aperture into which a securely held but freely moving locking member drops, motion of the former can or cannot be effected, according to the position of the latter. Thus in Fig. 164, *D* is a rigid stationary plate having an aperture, *S*; *C* a movable plate connected to the lever to be locked; and *L* the armature of an electromagnet, *R*. If *A* be an unlocking controller, when it is moved in the direction of the arrow its contacts will be closed and a current pass from *B* through *R*, raising

L and unlocking C, and thereby rendering the lever free. Conflicting routes may thus be protected electrically.

A section of one form of switch lock is given in Fig. 165. Within a suitable housing, H, is placed an electromagnet, A, whose armature, B, carries a locking piece, F; the latter engaging

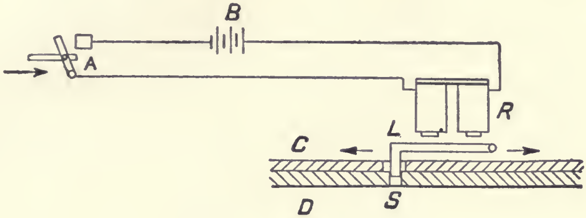


Fig. 164

with a slot or recess in a rod, E, connected mechanically with the switch point. Before the switch can be thrown, E must be free to move, which will not be the case if the armature is down, due to the locking which occurs by F falling into both a slot in the boss, D, and the rod slot. When current passes

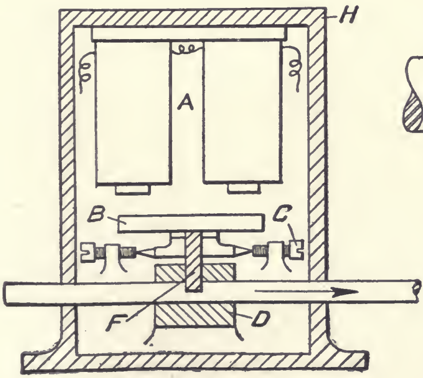


Fig. 165

around A, B will be raised and E free to move. At G another form of recess is shown, which has obvious advantages. B is carefully adjusted by means of the pivot screws, C.

Electric locks are most frequently used to regulate independently the function of the devices they are supplementary to.

As their application is varied, a large number of different types are in use. In Fig. 166 an electric lock applied to a mechanical interlocking machine is shown. The armature, *F*, of the electromagnet, *M*, carries a locking piece, *E*, which rests between the stationary lugs, *A*, and a recess in the piece at the rear of *D*, which is integral with the dog, *G*, of the locking bar, *C*; hence *C* cannot be moved unless *M* is energized. *B* is a banner which moves before an aperture in the housing, *H*, and is secured to the lock piece, *E*, serving as an indicator to the operator of the position of the lock bar.

Electric locking is sometimes applied as an intermediary to

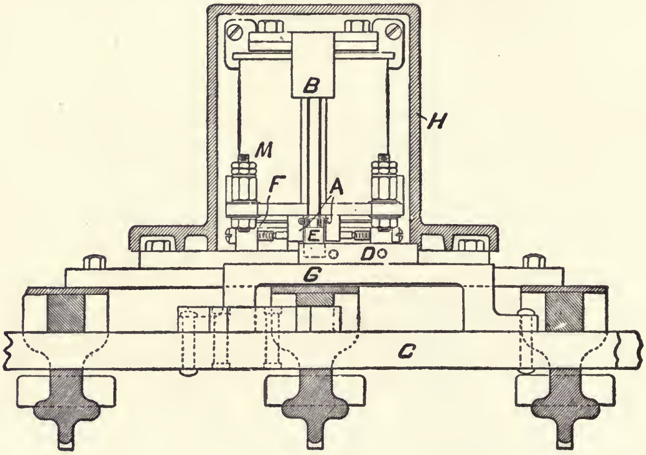


Fig. 166

derails or switches, so that the cleared home signal (mechanical) of an approaching train renders effective this locking, the release being arranged to act subsequently, providing the train has entered an unlocking track section and the home signal has been thrown to the stop position: the latter having to occur prior to the passing out of the train from the releasing section. This leads to the consideration of electric releases (although mechanical releases have been more extensively applied).

Electric releases are adjuncts which allow of a temporary manipulation of interlocked devices by the introduction of a supplementary or compensating feature; so that the interlock-

ing machine can be set normal under specific conditions. This release must be returned to its normal state (and consequently the electric locking made effective) before any routes can be set up for approaching trains.

In Fig. 167, *B* is a battery in series with which is connected a stick relay, *R*, and the normally open contact-springs, *C*; and whose armature contact is in series with the normally open contacts, *K*. *N* is a nut which moves along the threaded rod, *A*, when the crank, *H*, is revolved. When *N* is moved upward, the contacts, *K*, are closed, but *B* discharges no current as the armature of *R* is down. When *N* strikes *C*, the latter are closed, thus allowing a current to pass through *R*. *M* is a circuit controller operated by throwing the lever to which it is attached, while *T* is a locking relay in series with the contacts, *K*, and energized when they are closed. To require the return of *N* to the normal position, both *C* and *K* must be opened, as the battery will have two multiple paths for the current, the first through the front contact of the locking relay, its coils, the circuit controller, and lock; the second through the contacts, *K*, the armature of *R*, the coils of *R*, and the circuit controller, the lock, *T*, being thus shunted, and consequently deënergized. When *K*–*K* are opened, however, this will not occur, and the locked functions will be released.

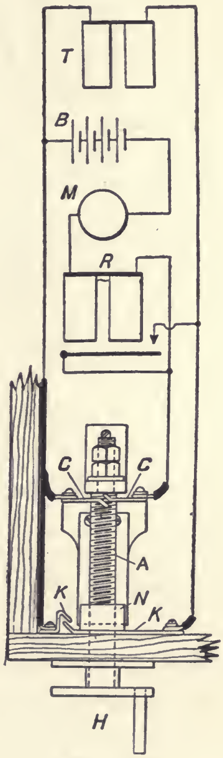


FIG. 167

This release arrangement is placed at some distance from the operator, so that some time will be taken to reach it, and this, in addition to that required in moving *N* up and down suffices to give the requisite time before the signal can be cleared for the changed route, assuring greater safety thereby.

Fig. 168 is a section of the sector block and lock employed in the Coleman arrangement. Within the housing, which is

fastened to the frame of the interlocking machine, is the sector block, *S*, which is moved about a center by the link, *C*, fastened to the lever, *D*, secured to the square shaft, *G*. *D* is connected to the unlocking segment, so that whenever the operator raises the latch preparatory to throwing the lever, it will describe an arc. Within the case is an electromagnet whose armature extension, *B*, drops into a slot, *P*, in the sector, a coinciding slot being also in the case. Hence, when the electromagnet is deënergized, *B* will fall into the slot and securely lock *S*. *B* also carries a banner through the projecting rod, *H*, which passes before an aperture, *A*, in the case, and indicates to the operator the position of *B*.

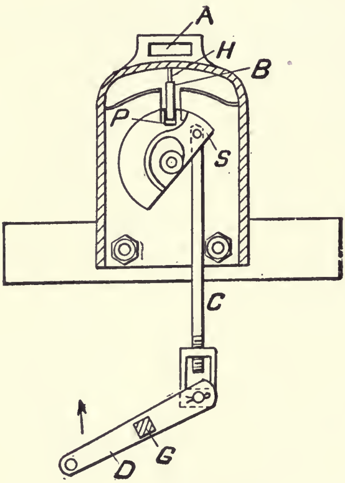


Fig. 168

By providing a circuit controller connected to a battery circuit in which a locking electromagnet is included, it is evident that a distant signal's movement may be employed to govern the movement of an interlocked lever. In Fig. 169 we have an interlocking magnet, *B*, applied to the lever, *A*, in such a manner

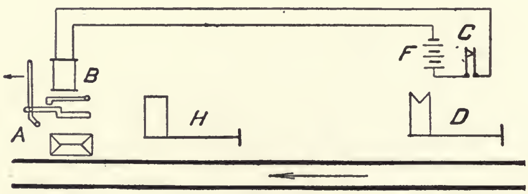


Fig. 169

that when its armature is down, motion of *A* in the reverse direction cannot be effected. When the interlocked lever has been thrown to its normal position, and the distant signal arm fails to assume the caution position, since the contacts at the controller, *C*, are open, it is not possible to throw the lever of the

home signal, H, to its full normal position. Hence such a route, and all other conflicting routes, are successfully locked until D has been cleared, thus raising the armature of B by the current from F. This provision is sometimes required to preclude the possibility of D's not working properly with its lever. Such an arrangement does not interfere with keeping both home and distant signals in their proper relation, or their normal indications, providing the levers are manipulated in proper sequence.

Fig. 170 combines the simple interlocking of the lever of the above case with an indicator and magnetic controller, the signals being in the clear position. C is in the latter position, due to its electromagnet being deënergized, a condition occurring when B is open. Thus C operates in unison with the distant signal, and if B is closed, will be in the caution position. The movement of the armature of C, beside setting the miniature signal,

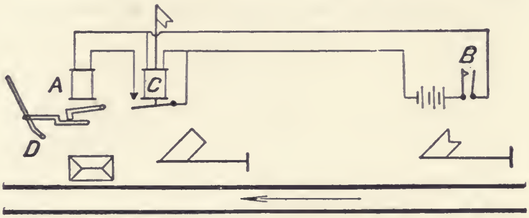


FIG. 170

connects the electric lock, A, in shunt with its magnet, thus energizing the former and releasing the lever. This release is usually effected on the latch of the lever which must be loose before the latter can be moved over its quadrant. Not only is less energy required to move the locking member in this case, but the liability to stick is also much less. The purpose of the above arrangement is to set the signals in their normal position, and still require that the distant signal be at caution before a route can be altered.

A circuit arrangement for the switch lock of an outlying switch controlled from the signal cabin is shown in Fig. 171. The operator's hand switch, C, is a two-point arrangement, the left-hand contact of which is connected to the relay, D, and in series with the contact, G, at the switch, B. S is a mechanically operated home signal having the circuit controller or commutator, F, the latter being in series with the switch-lock magnet and relay, H, so that when S is cleared H is deënergized, and con-

sequently locks *B*. *H* also has an armature and contacts, *I*, while *M* is a push-button, or switch, at *B*; *L* is a bell, connected to one side of the main battery, the latter being also connected to the common line-wire.

If a freight train at the siding, *B*, desires to move to the main line, the conductor presses the button, *M*, which causes *L* to ring in the cabin. If the operator can allow the switch to be thrown open, he moves the hand switch lever to the right-hand contact. If *F* be closed, a current will pass from the main battery over the common line-wire to *H*, *F*, *E*, and *C*, thus energizing *H* and releasing the lock. A train cannot now pass in the direction of the arrow, since the semaphore at *S* is at danger.

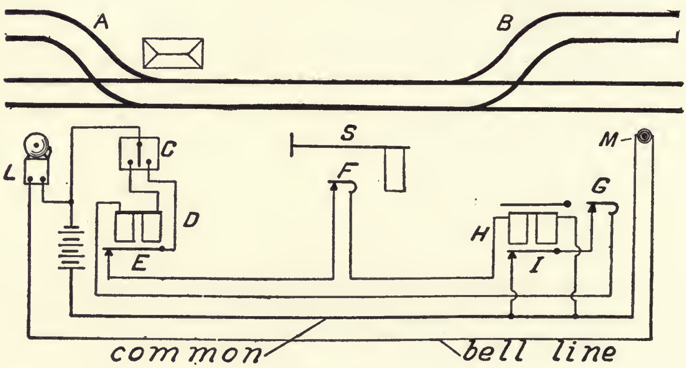


Fig. 171

Also, if the lock, *D*, were energized, its armature, *E*, would be raised, thus opening the circuit and preventing *H* from being energized. The train could not proceed from *B* if *S* were at clear, as *F* would be opened.

Should a train desire to proceed from the siding, *A*, to the main line, the reverse operations occur, the hand switch lever being moved to the left-hand contact. A current then passes through *D*, raising its armature and releasing the switch lock. *C* must now be closed and *H* deënergized, so that the armature, *I*, will close the circuit. This cannot occur if the switch at *B* is open, or *H* is energized. *D*, however, may control a signal, so that a train movement on the main track can be allowed only when it is energized; that is, *C* must be in the left-hand position.

In Fig. 172 a control circuit, such as is used in connection with a train staff on a single-track line with sidings, is shown. The main line is connected to a siding by the switch, 1. From the block tower, 9, the home signals, 2 and 22, are operated, 11 being a circuit breaker operated by the semaphore of 2, while 17 is operated by the insertion of a train staff; and when the latter is closed, relay 19 is energized.

The removal of the staff opens this circuit, but the relay remains energized, since a current flows through it by reason of the armature, 18, of the 4-ohm track-relay, 23, being up. This also closes the slot circuit, causing a current to pass through

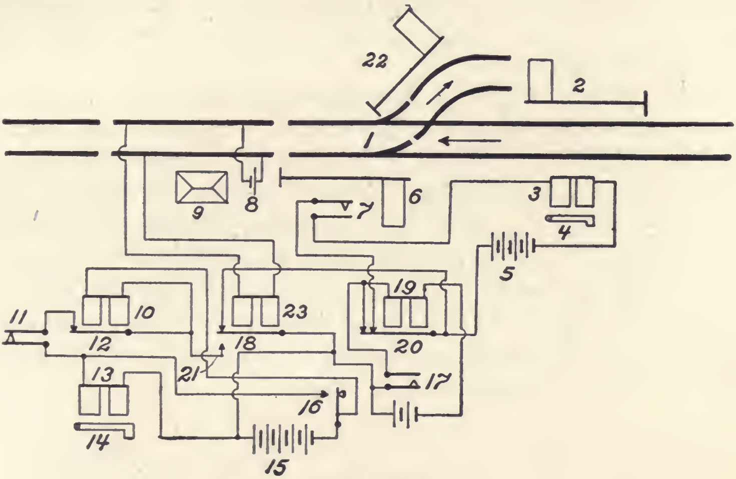


Fig. 172

the coils of a slot or lock magnet, 3, whose armature, 4, controls the movement of the main line signal, 2, which must be cleared in order to allow a train to proceed in the direction of the arrow. When 22 has been cleared, which will occur when the switch, 1, has been opened, a staff is inserted and therefore the circuit closer, 7, operated.

When this signal is cleared, the circuit through the lock magnet, 13, is broken at 11, which allows the locking function, 14, to fall, the latter locking the switch rod in place. The switch cannot therefore be opened until a train has passed over the insulated section to which the 4-ohm relay is connected. The engineman of a train passing into the protected section

removes the staff at 7, thus opening this circuit and causing 2 to pass to the danger position. The track being short-circuited, the 5-ohm relay, 19, is deënergized, and the 9-ohm relay, 10, energized. After the entire train has passed over the track section across which a difference of potential is maintained by the battery, 8, the 4-ohm relay is again active, which allows the switch to be thrown to its normal position.

The signal, 6, may be a distant signal, or one showing the condition of the main line for trains taking the siding. 15 and 5 are slot batteries, and the armature, 18, has a lower contact, 21, which is in series with 12 and 10. 16 is a hand switch provided to unlock 13 through battery 15, in case it becomes necessary to move a train in one direction before another can proceed to that point.

Detector bars may sometimes be replaced by short insulated track sections introduced at the switch to be governed, electric locking being also provided. In electrical power interlocking, special track relays having contacts capable of carrying and breaking heavy currents are necessary. These have non-fusing carbon contacts of great area, a wide break being interposed when the relay operates, in some cases requiring also a magnetic blow-out. The locking-circuits are usually independent of the power circuits control in such cases; but their application need not be entered into here.

CHAPTER XIV.

ALL-ELECTRIC INTERLOCKING.

Numerous types of interlocking are in use, in which the operative agencies are either partly mechanical, or mechanical with electrical control. The General Railway Signal Co., however, manufacture apparatus in which both working and control functions are electrical, a mechanical interlocking frame being used as an auxiliary to the levers. An early form of this apparatus (known as the Taylor) will first be described.

In Fig. 173 the connections at a double route signal, 37, having two home blades, one of which protects the main track and the other a diverging track, 44, are shown. A derail, 28, is also in the block of 37, and is operated by a motor, 12. This diagram is completed by Fig. 174, which represents the connections at the interlocking cabin pertaining particularly to 37. The motor, 49, operates 44; 28 is thrown by 12, while both arms of 37 are cleared by 31. The line wires, 1, 2, 3, 4, 5, 6, 7, 8, and 9, pass to the interlocking machine, 45 and 38 running to the distant signal protecting the home block of 37.

The motor, 31–32, operates either of the home semaphores, according to which selector magnet, 29 or 30, is energized. A circuit controller, 33, is in circuit with the motor, 31, and the brake magnet, 26. The contacts, 46, are in series with the wire feeding, 31 and 26, and are provided so that a clear signal will not be given when the derail is open. Should the derail be in the opposite or safe position, these contacts will be closed. Such a precaution is necessary in high-speed train movements, as an open derail would cause a wreck.

The track is energized by the battery, 27, the relay being omitted. The rotation of 12, and consequently the throwing of 28, moves the pole changer, 18, the function of which will be shown later. At 44, the motor, 48–49, is also connected to a pole changer operated by the switch movement. Contacts 11 are controlled by 44, being closed when the latter is open,

while the contacts, 10, are at the same time open. 10 is in series with 30, and 11 in series with 29, so that when one semaphore at signal 37 is cleared, the other cannot be, since but one route at a time can be set up.

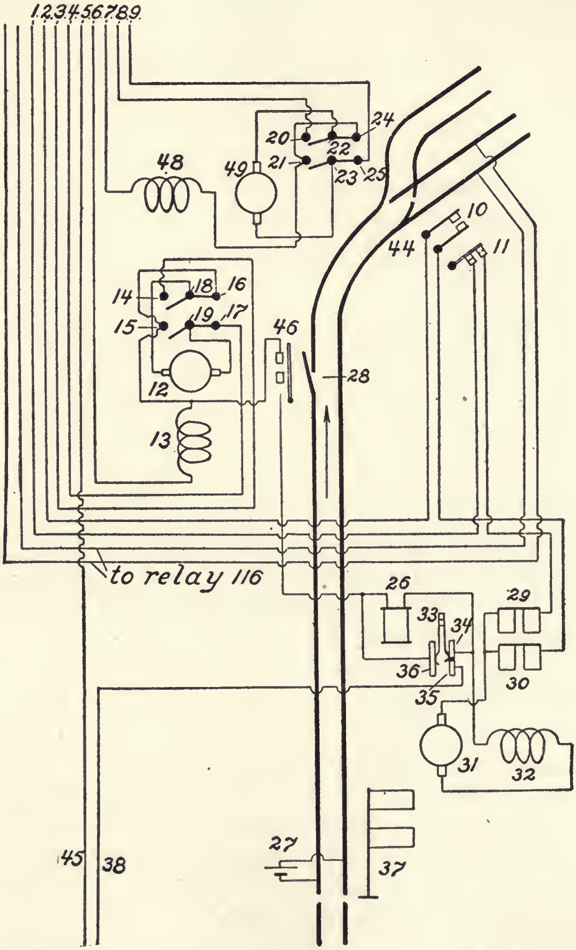
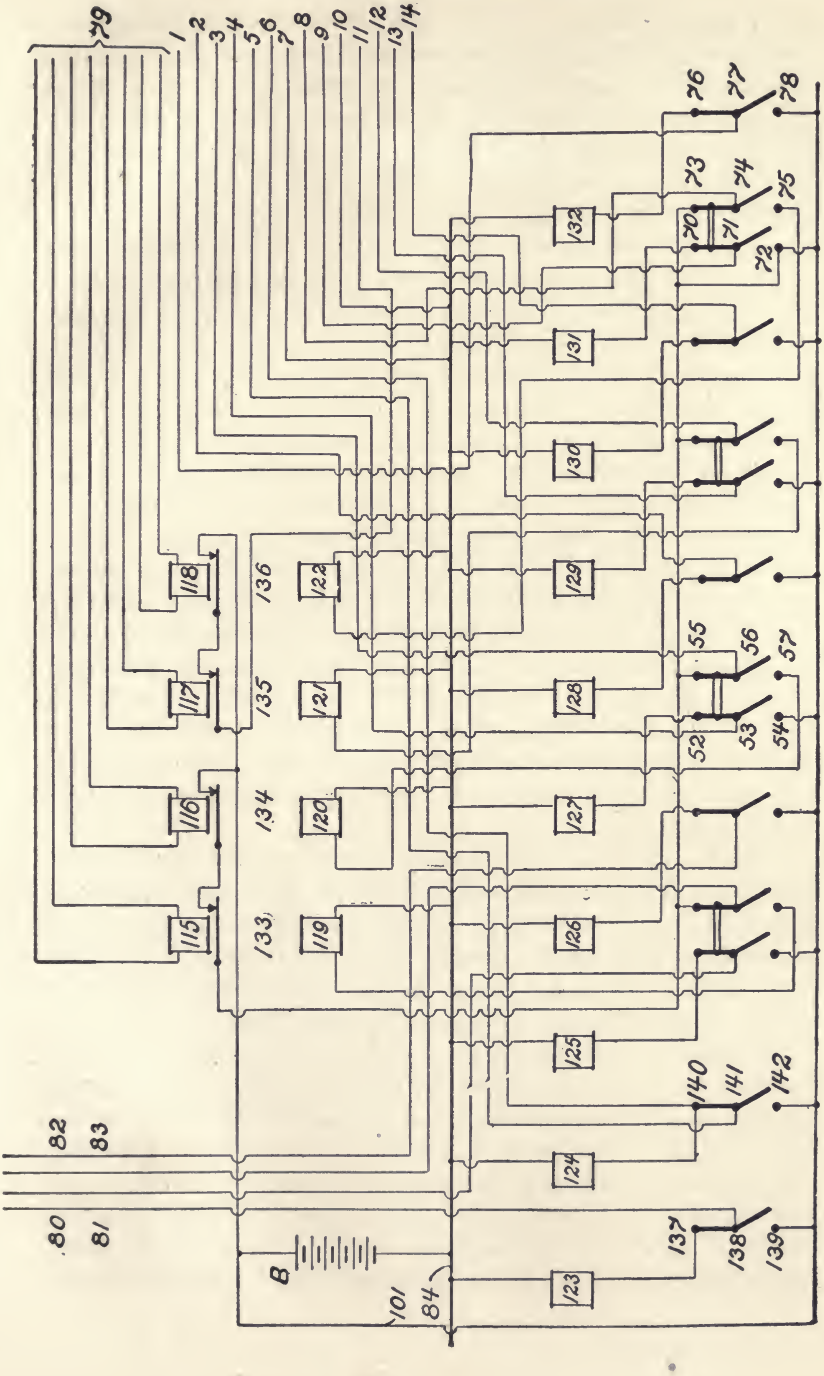


Fig. 173

In Fig. 174 the connections at the cabin are shown. *B* is a 60-volt storage battery; 115, 116, 117, and 118 are track relays, having contact armatures, 133 to 136, for carrying heavy currents; 119 to 122 are latch-releasing magnets, which when ener-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B
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FIG. 174

gized permit the levers (bars with handles, having a horizontal movement) to which they are connected to be moved; 123 to 132 are indication magnets, which give an indication of switch or signal movements; while the row of switches in the lower part of the figure are pole changers and connectors actuated by the levers themselves when the latter are thrown. The wires, 79, pass to the ends of the sections in which the track relays are introduced; the lines, 1 to 14 (only 1 to 9 are relevant to this description), run to the arrangement given in the preceding figure, and have the same significance; 80 and 83 pass to preceding switches, while 81 and 82 are signal wires. 84 is a common wire connecting one side of the battery, all the electromagnets, and several of the line wires. There are 10 lever (the levers themselves being omitted) circuits; they being distinguished by the fact that each has an indication magnet; signal levers opening one contact and closing another, while the switch levers open two circuits and close two during movement.

The armatures, 153 and 136, also 133 and 134, are in series, so that should either fall the circuit will be opened. Lines 7 and 10 are connected to 84; while 11 is a battery line in series with 135 and 136; 12 and 13 being switch lines and 14 a signal line. In tracing up a lever's circuit, it should be remembered that the order is changed after a rail switch or signal has been thrown, by reason of the electric switches thus opened or closed, and that single switches are for signal, and double switches for switch movement.

Consider, for instance, signal lever 123. (The levers are supposed to have the same numbers as the indication magnets.) When the lever is "thrown" 137 will be disconnected from 138, and 123 therefore deënergized. Immediately after, 138 will be connected to 139, and a current flow from *B* to line 80, and the signal (provided conditions are safe) at the latter.

Considering switch lever 131: When the switch is closed by the lever a current flows from *B* through 134 and 133–72 and 71–line wire 9– to Fig. 173–25 and 23–49–22–21–24–48–line 7–Fig. 174– common wire 84, and back to *B*. Since 48–49 begins its rotation, the switch is thrown and the current reverser 20–25 is operated, so that the next time 131 is thrown the motor armature will revolve in the opposite direction, and consequently moves the switch back to its former position. The current will

then pass through line 8 instead of 7. The switch movement cannot occur unless 115 and 116 are both energized, which requires of course a clear track and the absence of conflicting routes. Relay 116 is connected to track battery 27 through the rails of the track between 37 and the next signal, while 115 is connected to the side route extending beyond switch 44. Hence when either 115 or 116 is deënergized, 44 cannot be thrown.

The reverse and normal currents to switch 44 are through the contacts, 133 and 134, as train movement over this switch may take place in either position, since it joins two routes. The reverse current is not required through the relay contacts in case of a derail, as a train does not move over such a switch when normal; and sometimes it is necessary to reverse it when the block is occupied, that is, when the track relay is deënergized.

Lever 127 is for switch 28, and levers 132 and 128 are for 30 and 29 respectively of the semaphores at signal 37. Tracing up the connections for 127, we have, considering that this lever has been pulled outward (and consequently contacts 52 and 53, 55 and 56 separated; with 53 connected to 54, and 56 to 57), *B*–101–54–53–line 4–Fig. 173–17–19–12–18–16–15–13–line 6–Fig. 174–140–124–84–*B*. By reason of the movement of the switch, by the rotation of 12, the polarity changer, 18–19, is reversed, so that 18 and 19 are disconnected from 16 and 17 and connected to 14 and 15. This closes the indication circuit and causes a current to flow from the switch motor, 12, through 18–14–line 3–56–57–120–84–line 6–Fig. 173–13–15–18. Thus 120 is energized, the lever latch is released and the latter can complete its stroke. This releases the lever of 30 (132) so that the lower semaphore of 37 can be cleared. When 132 is reversed, 77 is disconnected from 76 and connected to 78. A circuit is thus closed including *B*–101–78–77–line 1–Fig. 173–line 1–contacts 11, (which are under the control of 44)–29–31–32–34–33–36–46–13–line 6–Fig. 174–140–124–84–*B*.

The clearing of the semaphore connected to 29 moves 33 in a downward direction and thus shunts the above circuit with the brake magnet, 26. As long as 132 is reversed, the upper semaphore of 37 will be at clear, while the connecting of 35 with 36 clears the distant signal preceding 37. Should 132 be returned to its normal position, 77 will be in contact with 76, as

in the figure. When the signal is returning to danger, 33 again connects 34 and 36, thus closing the circuit through the motor 31–32, and the indication magnet, 132, of Fig. 174.

The effect of gravity is to give the armature, 31, a rapid rate of revolution, which sets up a counter current and dampens the fall of the blade. This current passes momentarily through the brake magnet, 26, which in addition to the retardation of the motor armature, prevents injury to the moving system from inertia. The energization of 132 also releases the lever latch and allows the lever to complete its movement, which could not occur did this release current not flow.

It will be noted that the indication furnishes to the operator the right to complete the lever stroke, since it occurs after the lever has started. This is similar in function to that of other schemes of power interlocking, the indication showing that the switch has completed its movement. This indication is used only on the switch levers, as will be noted in Fig. 174, there being but four such indication magnets.

A later development of the above circuit arrangements is shown in Fig. 175, in which the track circuits (which may be either polarized or neutral) are not considered. In defining the functions and their relativity, the previous figures will not be considered, although an extension of the principle to a more elaborate though concentrated and isolated case is the object in view. Two sets of interconnected (by eight lines or wires in underground conduits) circuits are shown: first, those at the interlocking cabin; and second, those at a distant signal, 1, a high home signal, 2 (protecting two separate routes), a switch movement, 3, and a dwarf signal, 4 (the single semaphore home signal, 5, being for movements in the opposite direction, and its circuits therefore not shown).

The tappet bars are given a vertical movement by the levers; cross locking being effected by the dogs, *d*, which are affixed to sliding horizontal bars, and the recesses, *b*, cut in the tappet bars. If a dog engages with a recess, and the former is immovable, it is evident that the lever to which this locked tappet bar belongs cannot be moved. In the figure, levers 1, 2, and 4 are immovable; that is, they are mechanically locked in position. Lever 3 is movable, however, since it is not engaged by any dog, and if it be pulled outward, its tappet bar will

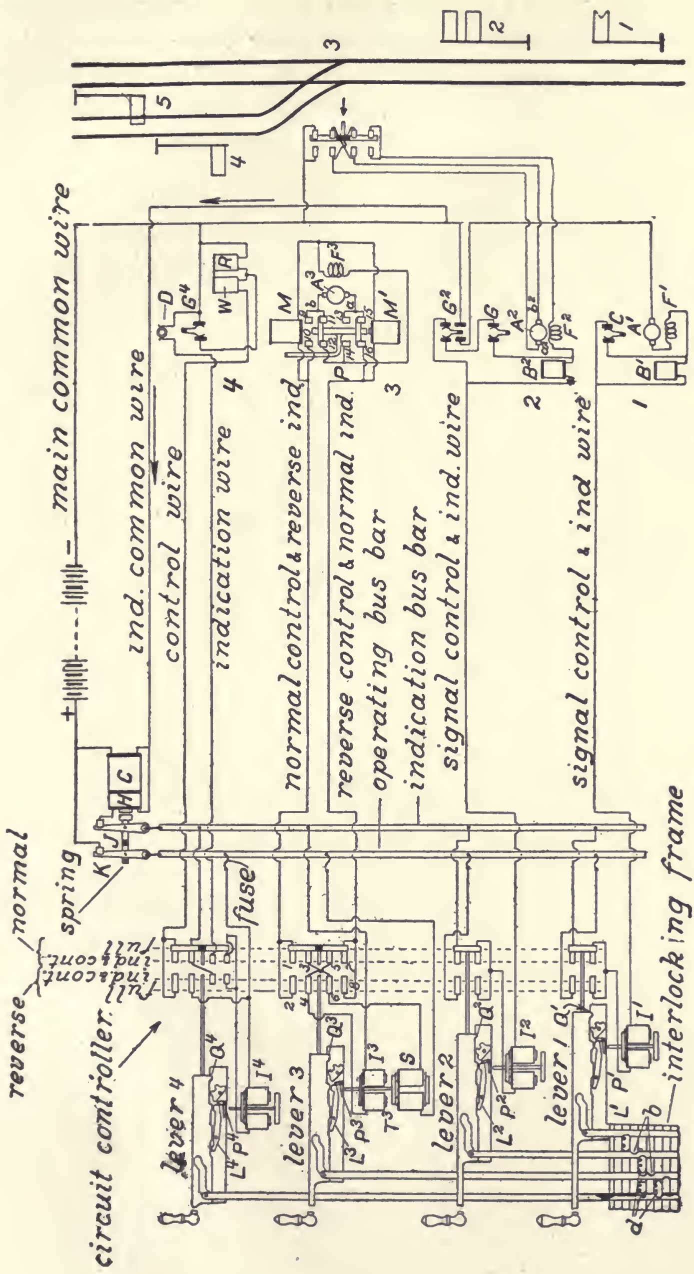

main common wire
ind. common wire
control wire
indication wire
normal control & reverse ind.
reverse control & normal ind.
operating bus bar
indication bus bar
signal control & ind. wire
signal control & ind wire
interlocking frame
circuit controller
reverse
normal
spring
fuse
lever 4
lever 3
lever 2
lever 1

FIG. 175

rise, thus unlocking levers 1, 2, and 4, since their dogs are now released by the action of the recesses. The levers operate the signals and switch of the same numbers, hence the latter are locked in the same fashion. It is thus evident that switch 3 must be thrown before the signals can be cleared, this sequence being manifestly required.

The cam slot in the lever transmits an intermittent motion to the corresponding tappet bar, which is for the purpose of preparing for a change in the circuits to which the lever is mechanically connected. The circuit controller consists of stationary and movable contact pieces, whose relation, though not their actual construction, is as shown.

The dwarf signal lever (4) and the switch lever (3) have each eight stationary contacts; the two remaining levers having but four, the reasons for which will appear later. The first half of the outward movement of levers 1, 2, and 3 produces no change in the connections, since the movable contacts engage the same brushes, and constitute the preliminary locking movement for the conflicting routes affecting this lever.

The central part of the lever stroke moves the contact pieces to the sets of brushes on the opposite side the tappet bar being stationary. The further motion of the lever is opposed by the latch, L (or L^1, L^2, etc.), which can only be released by the energization of the indication magnet, I, which will allow of its travel being continued until the end of the stroke is reached. This final movement further raises the tappet bar, releasing the dogs and bars controlling conflicting routes, and preserving the connections obtaining at the beginning of the last half of the stroke. The switch movement will first be considered.

To the main common line the indicator common, all the signals, and the switch movement are connected, either directly or through a circuit-breaker contact. The switch movement is controlled by two other wires, through which the indication current passes, with the indicator common. The control wire in the normal position is, in the reverse position, the indicator wire, both being used at a time. These two wires are connected to opposite brushes of the circuit controller, so that reversal of polarity can be effected by straight motion of the controller rod from the lever. In the position shown (which is normal)

the indicator wire is connected to the indication common through the indication magnet, 1^3, and the indication bus-bar, while the control wire is connected to the positive side of the battery through the safety magnet, *S*, and the operating bus-bar. In the reverse position these connections are reversed, as above stated.

Additional control of the switch movement is effected by the polarity changing arrangement, *P*, which is operated by the switch-lock bolt after it has passed through the lock rod and adjacent plates. This pole changer has eight fixed contacts and two movable contact plates. Each of the motor armature terminals is connected to two of these fixed contacts, each control wire to one, and one of the field terminals to the remaining two, the other field terminal being joined to the main common. This connection arrangement, through the action of the other movable contacts, connects in the one case (that shown, or normal) *A* to the indicator wire and *b* to the field, F^3; and in the reverse position, *A* to the field and *b* to the reverse indicator wire. In the former position, also, the pole-changing switch is disconnected from the normal control; no current flowing, although this control is connected to the battery. Reversal of the switch lever, however, will connect the reverse control wire with the battery, a current flowing through the following circuit:

Battery–*K*–operating bus–safety magnet, *S*–circuit controller contacts, 6 and 8–reverse control wire–contacts 16 and 15–A^3–contacts 11 and 12–F^3–main common–battery. When the switch has completed its movement and is locked in position, the lock rod throws the pole changer, so that contact 9 is connected to 10, and 13 to 14. The reverse control wire is thus disconnected from the armature, *b*, and connected to the reverse indication wire, while *a* is connected to the field coils; the reasons for which will appear shortly.

The safety magnet, *S*, and the indication magnet, I^3, both have their poles facing, and capable of acting upon the armature, *T*; this armature normally resting upon the poles of the safety magnet, which is in series with the battery and both control wires; the one in circuit depending upon the positions of *P* and the switch lever circuit controller. Should a break occur in any of these wires or in the safety magnet, coils *S* will not be energized.

If a cross or short circuit occurs between the control wires, the total current, both that passing to the switch motor, and that through the indication magnet, will pass around S, so that should all the current pass through the indication magnet on return, it will not exceed the current in the former; hence the armature will be held by S, and the indication cannot be given. As the armature normally rests upon the poles of S, in which case the air-gap is zero, and the magnetic reluctance low, this probability is further increased. Thus it is practically impossible for a cross to set up a false indication.

A motor when operating sets up a counter electro-motive force which opposes that of the operating current. If the latter be suddenly cut off and the armature immediately connected to an independent circuit, a current will flow in the latter (its strength determined by the counter e.m.f. and total resistance in the circuit) in the opposite sense to that of the driving current; and will be maintained by the inertia of the armature and mechanically connected parts. This is precisely the effect which is utilized to give an indication through I^3, the proper connections being effected by the pole changer. The circuit thus formed for the indication current is: terminal a–F^3–main common–indicator common–magnetic cut-out, H–switch J–indication bus–I^3–circuit controller contacts 4 and 2–reverse indication line–pole changer contacts 10 and 9–armature terminal b. The current thus flows in the same direction as before through the field, hence its magnetic flux is unaltered, while the indication magnet releases the switch lever by reason of the following:

Normally, the latch, L^3, is held in the position shown by the dog, P^3, and prevents full outward movement of the lever by the engaging of projection Q^3 with the projection on the right-hand end of L^3. When I^3 is energized, however, T^3 is moved upward, and its rod strikes dog P^3 so that L^3 is released and allowed to drop, permitting the completion of the lever stroke. (It should be remembered that the travel of the lever has already been traced to its middle position.) Hence the indication current cannot be set up before the motor-operating current has been cut off, the indication wire connected to one side of the armature, and the connections between armature and field reversed. The cessation of operating current might be produced

by a broken conductor, which is a highly improbable condition, while crosses are guarded against by S.

The magnets, M and M', are in series and connected to the indicator and control line-wires, their junction being also in connection with one terminal of F^3 and consequently the main common. By means of these magnets, the movement of P is under the control of lever 3, at such times as it is not operated automatically by the lock rod. When the battery is connected to the normal control wire, current energizes M; but when the reverse control wire is in connection with the battery, M' is energized. These currents shift the pole-changer mechanism in the direction of the magnet through which the current circulates, hence movement can be effected at any time during the switch- and lock-rod-movement, except at the very beginning and ending of the latter. If the lever is used to reverse the switch, current passes through the motor and through M'; this current so holds the pole changer that the operating current will be maintained. Should it be desirable to throw the switch normal before this reverse movement has been completed (which contingency might arise from snow, ice, or other obstruction between the main and point rails), the lever is merely pulled back to the normal position, thus energizing M through the normal control wire and throwing the switch back. This is effected by M shifting P to its former position, sending current through the motor in the proper sense by way of the normal control wire; the pole changer being again shifted to the position shown, thus setting up the indication current. When M shifts P, current does not pass through I^3, since the lever controller is not in the proper relation with the pole changer, and current is not set up if the magnet refuses to operate, on account of the reversed armature connections. A circuit-breaking device is in series with M and M', so that when the switch has fully moved and is locked in either position, the current is cut off from these magnets. This does not alter the rest of the diagram, however.

When the lever, 3, is moved to the normal position, the battery is connected to the normal control wire through S, thus sending a current through the switch motor, which starts at a and returns to b, in the opposite sense to that used in reversing the switch, the field current maintaining its proper course. The armature thus revolves in the opposite direction, the switch

rails being thereby thrown normal, and at the completion of this movement, P is shifted to the position shown in the diagram, the indication current being thereby set up. Terminal b is thus open-circuited, while a is put in series with the normal indication wire, which at first was the reverse control line.

The switchbox contains a pole-changing device which controls the motor of the two-home-arm high signal, 2. When the motor revolves in one direction, one of the semaphores is cleared, and when in the other direction, the remaining blade. This switch thus acts selectively, the semaphore being connected by a chain to opposite sides of a sheave wheel driven by the motor through reduction gearing. Hence, when one semaphore is cleared, the other must be at danger, gravity producing this latter condition through the medium of counterweighted levers, which are mechanically connected to the blades.

Each semaphore operates a circuit breaker, the upper arm having two sets of contacts, and the lower one set. One of the former closes the circuit of the distant signal, 1, the lower arm not having a distant function. The lever, 2, which controls this home signal, operates a controller having one reverse and one normal pair of fixed contacts, but one movable piece being used. Only one line wire, the control and indication, passes to 2, and is in series with I^2 and the lower set of fixed contacts. One of the upper contacts is connected to the indicating bus, and the other to the operating bus. When lever 2 is reversed, the positive side of the battery will be connected to I^2 and the control line, a current flowing through the circuit including I^2–control line–G^2–G–F^2–switchbox–a^2–A^2–b^2–switchbox–main common–battery. If the switchbox is in its normal condition, the upper arm at 2 will be cleared. Upon the completion of the movement to clear, G^2 opens the home circuit and closes the distant circuit, the motor-brake magnet, B^2, being in shunt across this break, this magnet having a comparatively high resistance and bringing the motor armature to a stop, holding the signal at clear as long as lever 2 is in this reverse position.

As I^2 is energized, L^2 releases the lever, so that the full movement to the reverse position can be made. This energization does not constitute an indication, as such is not required, since locking is not released. The movement of the distant

signal, 1, to the clear position is the only indication required of the proper clearing of this upper blade, this being accomplished by the interposed circuit-breaker. When lever 2 is pushed back to normal, the brake-magnet circuit is broken, and the indication magnet connected to indication common and the control line. Hence the brake mechanism is released, the blade returning to normal by the action of gravity on the counterweight. This sets the train of gears and motor armature into rotation, developing a counter e.m.f., the circuit-breaker, G^2, also closing the indication circuit in its upper position. This circuit includes A^2–b^2 switchbox–main common–indication common–H–J–indication bus–1^2–control line–G^2–G–F^2–switchbox– and a^2. The latch, L^3, is thus released, so that the final part of the stroke of the lever, 3, can be made. The energy expended in this releasing circuit retards the moving armature and prevents a blow being delivered by the moving parts.

If the switchbox switch is reversed when lever 2 has been reversed, the current will pass through the armature from b^2 to a^2, in the opposite direction to that above shown. This, therefore, causes the armature to revolve in the opposite direction, thus clearing the lower arm, the indication current being developed in the same manner as above described, the brake magnet, B^2, being put in circuit by the action of G, with which it will be in shunt. The indication current is also in the opposite direction in the armature and switchbox.

The dwarf signal, 4, is not thrown to clear through the aid of a motor, but directly by the movable magnetic circuit of a heavy solenoid. This solenoid has two distinct windings, represented in the diagram by R and W. R is the retaining coil, and is of high resistance, holding the small semaphore at clear, while W is the working or clearing coil, and of comparatively low resistance. The indication current is taken directly from the working battery by way of the signal's lever, 4, instead of utilizing the counter e.m.f. of a motor, it serving equally well. The circuit controller has eight stationary and two movable contacts as before; four of these fixed contacts being shorter, however, so that the movable pieces will not dwell upon the former more than a predetermined time.

A normally fixed connection exists between the indication magnet and the positive side of the battery, the indication line

being connected to but one of the short fixed contacts. The indication line is connected to a circuit-breaker, D, at the dwarf signal, another circuit-breaker, G^4, being in series with the working coil. The latter is closed only when the signal lever is reversed, while D is closed only when the signal is normal. When the lever is at the normal indication position, the control line is connected to the indication bus, and the other end of the indication magnet to the indication wire. At the reverse indication position (when the movable contacts are in the dotted line denoting the reverse indication and control points) the positive side of the battery is in connection with the control wire, the indication magnet being in series with the indicator and main common lines, and the negative side of the battery.

At the full normal and reverse point, the indication magnet is open-circuited, and the control wire is connected in a manner similar to the indication and control positions. When lever 4 is reversed, current flows through the control wire to W, to the main common battery, and circuit-breaker, G^4, thus clearing the semaphore; G^4 then opening, cutting in R (and W, which is in series with it, although now having but little magnetizing effect) which retains the blade in the clear position. The clearing current is about 6 amperes, and the retaining current .25 ampere.

The indication current, which is sent through the indication magnet when the lever has reached the normal indication position, is not set up for any other purpose than to release the lever and allow the full reverse movement to be made, as in the case of the high signal, the reason for this being that an interlocking function is not to be released. When the lever is moved back to normal, R is open-circuited, and the blade moves to danger, thus closing the circuit-breaker, D, and connecting the main common line to the indication line. A latch releasing current then flows through I^4, because the latter has been connected to the indication line by the movement of the lever to normal.

The indication common is not connected to the main common at the cabin; but is run out to a point where the effects of voltage drop in the main common, due to the heavy current taken by the motors, etc., will be at a minimum. Should this line be near the battery, the drop in potential would have a tendency to cause a current flow back over the indication lines of the levers not being operated, and might open the safety cut-out

(to be described) when not required, resulting in considerable annoyance.

This cut-out is provided to eliminate the evil effects resulting from crosses between any of the various wires. *J* and *K* are two switches connected respectively to the indication and operating buses, being normally held open by a spring, and closed by current in the coil, *C*. When *K* is open, it cuts the battery off from all functions, while *J* opens all of the indication circuits. Coil *C*, which is of high resistance, is connected across the battery through the main and indication common lines. *H* is a low-resistance coil, wound differentially with respect to *C*, so that the greater the current in *H* in a given direction, the greater the opposition to the flux of *C*, and consequently the less the pull on the armature. *H* is in series with the indication common, so that all indication currents must pass through it, these currents moving in the direction of the arrows, and assisting *C* to maintain the contacts at *K* and *J* closed. Any current flowing from the positive side of the battery through *H*, due to a cross, will pass in the opposite direction to the arrows, and consequently tend to neutralize the flux set up by *C*, and open the cut-out, as the indication common, to which *H* is permanently connected, is on the negative side of the battery. All wires connected to the interlocking machine which are functionally operative are connected to the negative battery terminal through the indication bus, *J*, *H*, indication, and main common; hence, current passing from any line-wire to these will set up a current which produces a flux in opposition to *C* and thus opens *K* and *J*. *H* has a low resistance, hence the greatest percentage of the current resulting from a cross will flow through it, and if this current be of sufficient strength to cause rotation of a motor armature, it will certainly open the cut-out.

In Fig 176 a portion of a standard all-electric interlocking machine is shown. A rear view, showing the fuse and terminal board, is at 1; 2 is a typical section, and 3 a partial front view of the locking. Besides a supporting frame, there is a terminal board, *A*, the controllers, *C*, levers *D*, lever guides *E*, locking *G*, case *H*, and indication and safety magnets, *I* and *S*. The case is provided with glass doors, for ready inspection and repairs, and the fuse board contains all fuses, buses, terminal posts and connections. The upper bus is the switch operating, the lower

the signal operating, and the central is the common indication bus. *B* is an indication selector, which is used only on switch

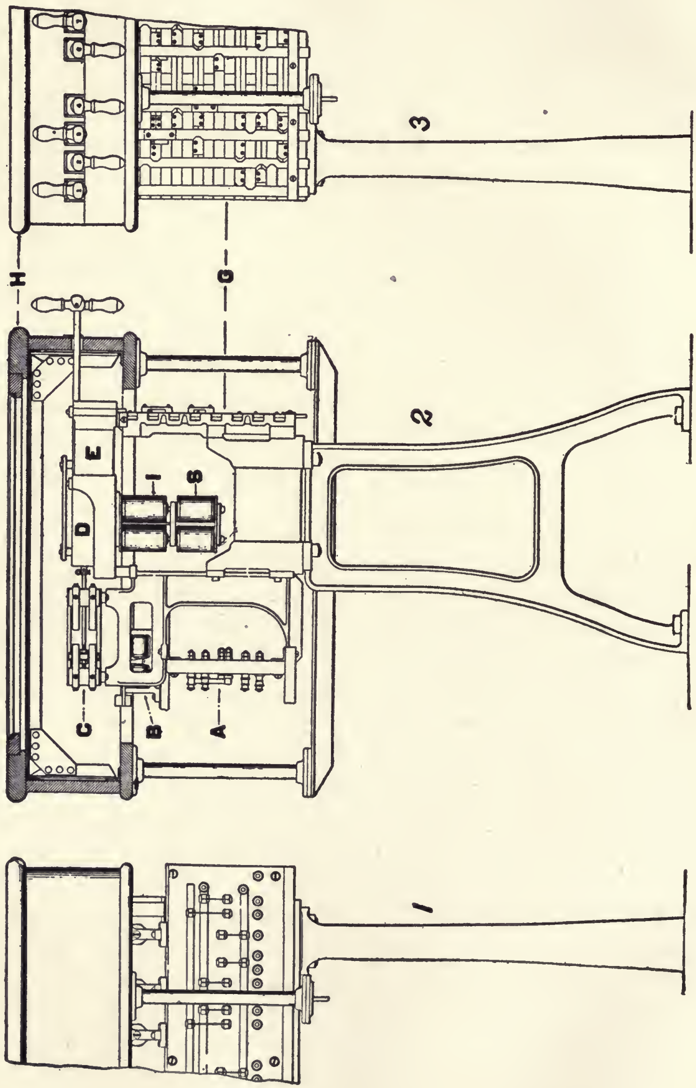


Fig. 176

levers, consisting of electromagnets operated by the working current, moving an armature in one direction when the switch

lever is normal, and in the other direction when at reverse. It closes the indication circuit corresponding to the lever position, leaving the other open.

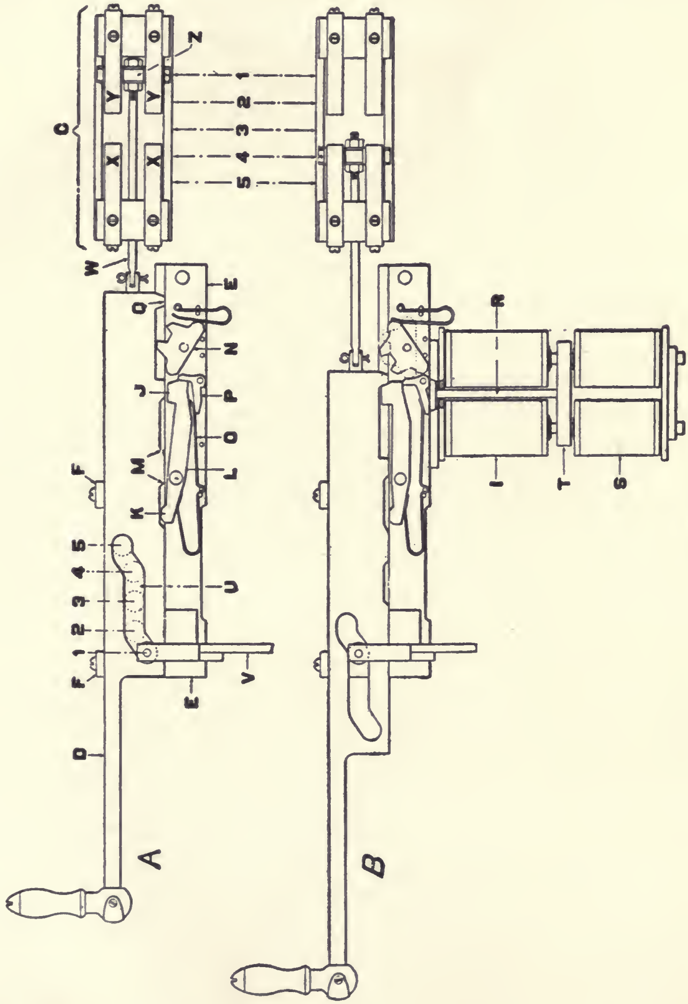


FIG. 177

In Fig. 177 the appurtenances directly common to the levers and their relation are shown. *A* shows a lever entirely in, and *B* the same four-fifths out. *D* is held in the guides, *E*, by the bars, *F*, and is provided with a slot, *U*, which imparts variable

motion to the tappet bar, *V*, the respective positions being numbered 1 to 5. The moving contact block, *Z*, receives motion from *D* by the rod, *W*. *I* and *S* are the indication and safety magnets respectively, and impart motion to rod *R* through the armature, *T*. *X* and *Y* are stationary contacts connected to the various functions, as shown in the diagram, Fig. 175. *R* engages with *P*, which is held down by the spring, *O*, the latter also acting against the pivoted latch, *L*.

The raising of the tappet bar, by the movement from 1 to 2, locks all the conflicting levers, the projection, *M*, then striking *K*, and tilting the latch, *L*, to a nearly horizontal position, causing *J* to be struck by *Q*, thus retaining the lever. When moving from 2 to 3, *Q* also meshes with the teeth on *N*, thus causing the latter to rock about its axis, and by throwing dog *P* into engagement with *L*, locking the latter, as at *B*. From 3 to 4, *N* continues its revolution, being stopped by *Q* striking *J*. Here an indication current passes through *I*, releasing *L* by reason of *R* striking *P*, allowing the motion from 4 to 5 to take place, thus unlocking the unconflicting levers by the upward motion of *V*. Hence, *D* will be immovable when conflicting routes are set up, and cannot move from 4 to 5 without an indication; while if it is moved to or beyond 3 it cannot pass 4 nor return to 1 without an indication, which will not occur unless the function controlled is locked in the position corresponding to that of the lever.

The switch and lock movement for a left-hand slip switch is shown in Fig. 178, and consists of the motor, *A*, and connecting shaft *B*, pole-changer *C*, gear frame *F*, driving rod *G*, lock movement *H*, and cover *L*. The motor is of enclosed and weatherproof construction, and operates the entire arrangement. The gear mechanism, *F*, reduces the speed of the motor armature for the required slow movement of the detector bar and switch, and disengages the motor after the full switch movement has taken place. This latter is effected by the cam, *D*, which is on the same shaft as the main gear, by the clutch shifter, *V* (which allows the shaft to revolve without affecting the pinion), and by toothed clutches, not detailed. Unless the pinion engages with one of the clutches, it is loose on the shaft, so that when the stroke is completed the clutch is moved transversely by a shifting-cam on the main gear, after which

the indication is given. The main gear-pin, *E*, moves the lock plunger, detector bar, and switch, through the rod, *G*, and crank cam, *D*. The lock movement, *H*, directly operates, the pole

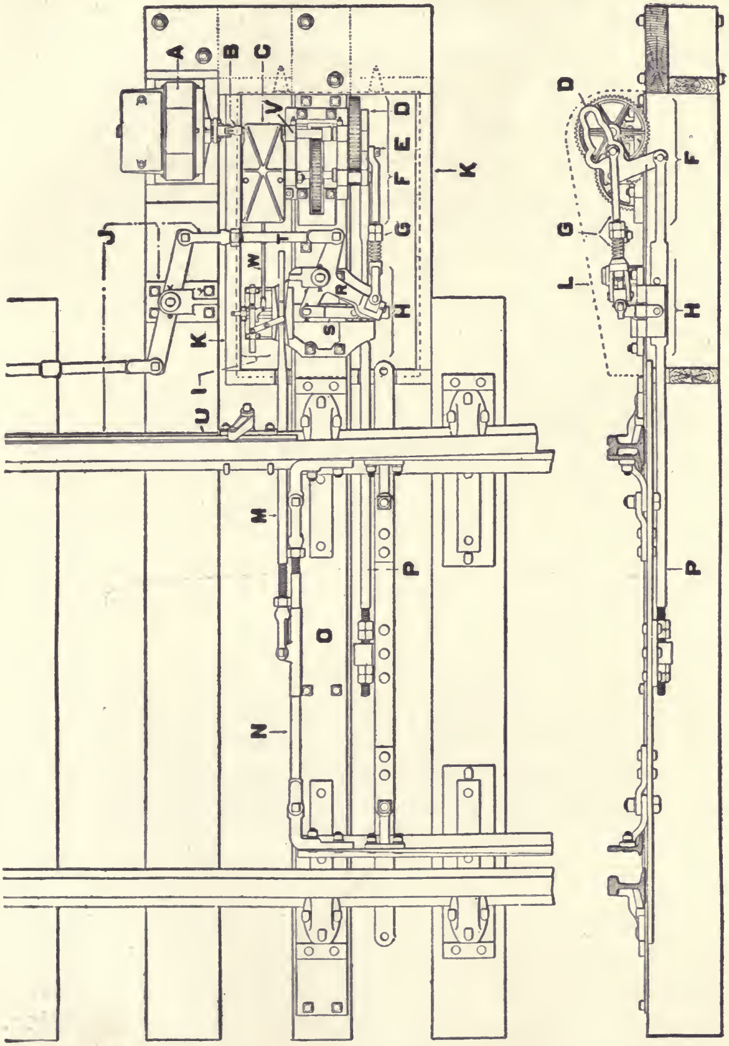


Fig. 178

changer, detector bar, *U*, and lock plunger. *G* throws *R*, and consequently *S* and *T*, so that the switch cannot be thrown if a train be passing it. *C* is moved through the medium of

the pole-changer movement, *I*, after the lock rod, *M*, is held by the lock plunger. The pole changer moves in one direction when the switch is moved normal and in the opposite direction at reverse, with results already shown diagrammatically.

The operation of the switch movement is as follows: When the switch lever has been thrown, and the motor connected to the battery, the armature drives the main gear through

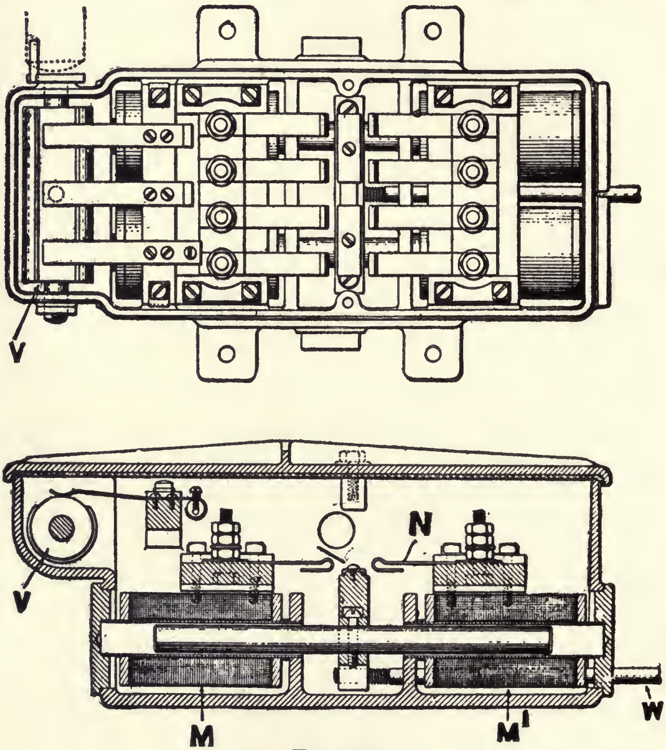


FIG. 179

one revolution. At the first part of its revolution the lock bolt is released, and the detector bar raised. The pin, *E*, then strikes the outer end of the pivoted cam, *D*, thus throwing the switch, this taking approximately one-third of a revolution. The remaining third of the revolution results in the lowering of the detector bar, and setting of the lock bolt, the pole changer being thrown as soon as the plunger passes through the lock rod, the motor disengaged, and the indication given.

The reversible pole-changer mechanism, shown in outline and connection at the switch machine and designated by *P* in the diagram, is illustrated in plan and elevation in Fig. 179. Rod *W* is connected mechanically to the lock bolt, and operates the movable contacts, which engage the fixed contact-fingers *N*. *V* is a control drum, acting as a circuit-breaker, which is operated by the shaft (shown dotted) carrying the main gear and cam so that the magnets, *M*, are open-circuited when the switch is home and locked. The movable cores, to which the moving contact blocks are secured, are under the control of the magnets when the switch is to be thrown. These magnets are shown at *M* and *M'* in the circuit diagram also.

A Taylor switchbox (or ground selector) is shown in Fig. 180. The movement of the switch rails throws the link, *C*,

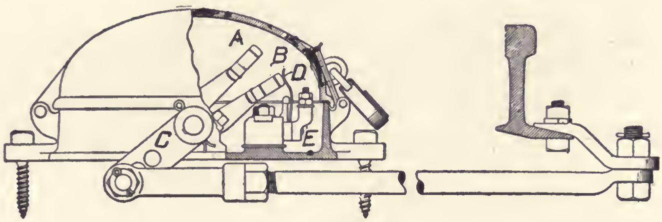


Fig. 180

thereby bringing the movable contact members, *B*, into connection with the row of stationary clips, *D*, closing the desired circuits. When the switch is thrown in the other direction the contact strips, *A*, engage with a similar row of contacts on the opposite side of the box. This device is used for any application of functions depending upon switch or other movement for their control.

Fig. 181 shows a Taylor hook selector, suitable for fastening to a signal pole and controlling a semaphore. *B* is the counterweighted lever, which normally has no connection with lever *D*. The latter is keyed to the shaft, *F*, while *B* moves about *F* as a center merely. When the electromagnet is energized, the armature, *E*, is raised, causing hook *C* to be thrown directly in the path of a cross piece, fastened to *B*, so that movement of the latter cannot occur without *D* being moved. Hence, when *B* is pulled in the direction of the arrow by the motor,

the signal will be cleared, if *A* is energized. When the interlocking lever for the signal is thrown, current passes through the proper selector magnet, through the motor and circuit

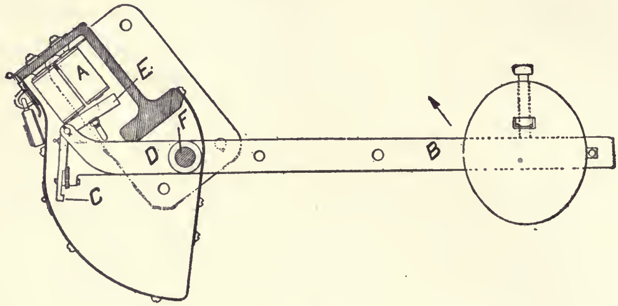


FIG. 181

breakers. This clears the signal, the indication being given in the usual manner. From two to five arms may thus be operated, and if ground selectors are used, but one interlocking lever is required.

CHAPTER XV.

THREE-POSITION SIGNALS.

THREE-POSITION semaphores eliminate the distant blade and still give an indication of the condition of the distant block. This is accomplished by using three distinct positions of the semaphore: the all-clear being vertical; the caution diagonal; and the stop position horizontal, or nearly so. The control and operation may be effected by either line or track circuits,

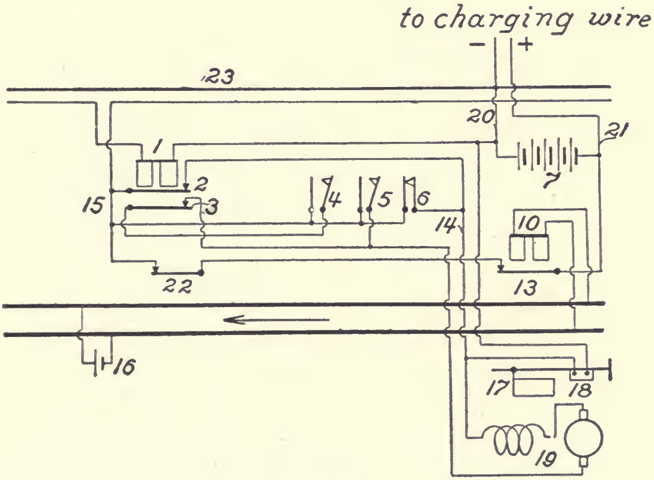


FIG. 182

the former being first described. Considering three consecutive signals, No. 3 being occupied, 1 and 3 will be controlled by the track circuits in the blocks they protect, while 2 will be controlled by line wires from 3.

Figs. 182 and 183 show the consecutive circuits employed in the Grafton arrangement of such signals. Fig. 182 gives the connections at the first signal considered; the semaphore, 17, being operated by a motor, 19, of about .1 horse power, its posi-

tion and movement being governed by the slot instrument, 18. The armature contacts, 13, of the track relay, 10, are in series with the cut-out, 22 (operated by the motion of the signal mechanism), and one side of the main or storage battery, 7, the latter being located at the signal, and charged by feed wires running on poles from a central generating plant, one side of this battery being connected to the common line, 23. If the contacts, 6, are closed, a current will pass through 18, which locks the signal and holds it in the clear position shown.

Should 10 be deënergized, however, by reason of 16 being

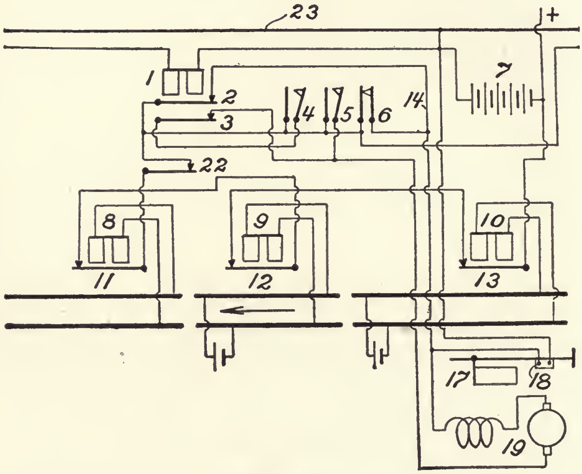


Fig. 183

short-circuited by a train in the section, 18 will be released and 17 will return to the stop position. Circuit-breaker 4 is closed when the signal is in either the stop or the caution position, but is opened in the clear position; while 5 is closed only in the stop position, and 6 closed in the clear and caution positions. The three-position relay, 1, is in series with the line wires, and has two armatures, 2 and 3; the former shunting the circuit-breakers, and the latter connecting the motor to one side of the battery through 4, 22, and 13. If the wires, 15 or 14 (Fig. 183), should be broken it is evident that 7 would be continually passing a heavy current. To guard against such an occurrence, the circuit opener, 22, operated by the signal mechanism, is provided.

The armatures, 11, 12, and 13, of relays 8, 9, and 10, are in series with this device.

The special parts of the signal mechanism are shown in Fig. 184. The semaphore is connected to the rod which is fastened to the sleeve, *F*, the accessories being secured to the latter, and move with it when the semaphore is cleared. The rod, *M*, is operated through a train of gears by the electric motor, there being three stationary positions. *B* is the slot magnet, whose armature affects the position of the lock block, *L*, through the toggle arrangement, *C–D–K*. *A* is a dashpot, whose piston is stationary, it being required to prevent spasmodic movements of the moving system, and prevent the inertia of the latter from injuring the mechanism. *N* and *J* are latches which engage with *F* at its various positions and relieve the motor and gearing of the weight of the apparatus when at rest.

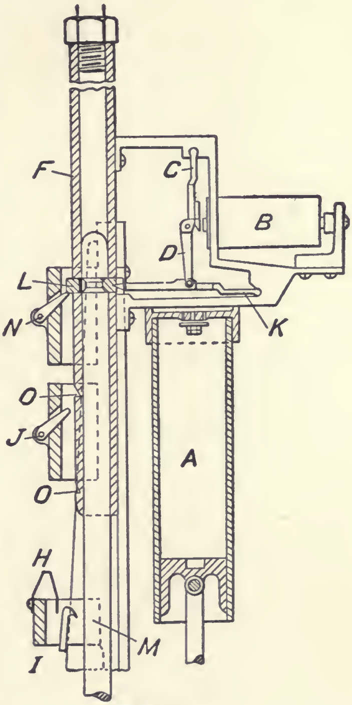


FIG. 184

When *B* is energized, *L* is forced into engagement with a recess upon the upper end of *M*, so that motion of the latter results in motion of the former, their tendency being to disengage. The circuit-breakers not shown are operated by an extension of the sleeve, *F*, while *I* is the armature extension of a catch magnet, which, when deënergized, prevents *F* from moving upward by the hooked end of the armature being forced into the notches, *O*, by the spring, *H*. The operation of the signal should be readily perceived from the above description, a rather complicated application in conjunction with semi-automatic signals being now taken up.

In Figs. 185 and 186, the connections of two automatic three-position signals on double track, and their relation to mechani-

cal semaphores, moved by levers from a cabin at a junction, are shown. Both 2 and 4 are electrically operated, but are also under the control of the signalman; while 1 and 2 are entirely automatic. In order to trace out the connections most expeditiously, Figs. 182 and 183 should again be consulted. Both diagrams are similarly arranged, and are connected by the line wires, 1 to 7.

At 10 in Fig. 185, the circuits at signal 1 are shown, the remainder of the figure being devoted to the connections of 2 and the interlocking functions. The circuit-breakers, 16 and 17, are opened when the semaphore of 1 is moving to the clear position, while 18 is closed,the three-position relay, 19, controlling signal 1, current being derived from the main battery, 11. Circuit-breakers 22, 23, and 24 are similar in function and operation to those operated by 1, while 25 is in series with one of the contacts of the circuit controller, 14. The latter is operated by the lever which throws 4 of Fig. 186 to the clear position, at which time the breaking device, 31, is closed. This effects a cautionary indication through the distant line wire.

The lock magnet, 27, is for the purpose of securing the lever for 4 in the stop position, unless it is energized by way of the common and No. 4 line wires, through 13 and the first of the set of contacts 32. When the lever of 4 is reversed, the lever relay, 28, is energized and acts as a controlled function; the stick relay, 38, through its lower armature, being interposed for accomplishing this purpose. The latter must be energized before the signal can again be cleared.

In tracing up the circuits it should be remembered that 2 is controlled in a manner similar to 4, and that while its connections are shown, only those of the latter are described. As the latch of the lever for 4 is lifted the circuit controller, 13, is shifted, so that the stick relay, 15, is connected through contacts, 36, and the upper armature of 15 and its coils, line-wire 4, and the storage battery. The lever relay, 28, has been closed through the storage battery, armature 37 of the control relay, 35 (of signal 4), line 7, 36, lower armature of 15, line 5, lever relay 33, line 3, and to the battery. When 13 is not shifted, we have from the battery, 37, line 7, 36, upper armature of 15, 15, line 4 to battery.

As 33 is on closed circuit when the signal latch is raised, it

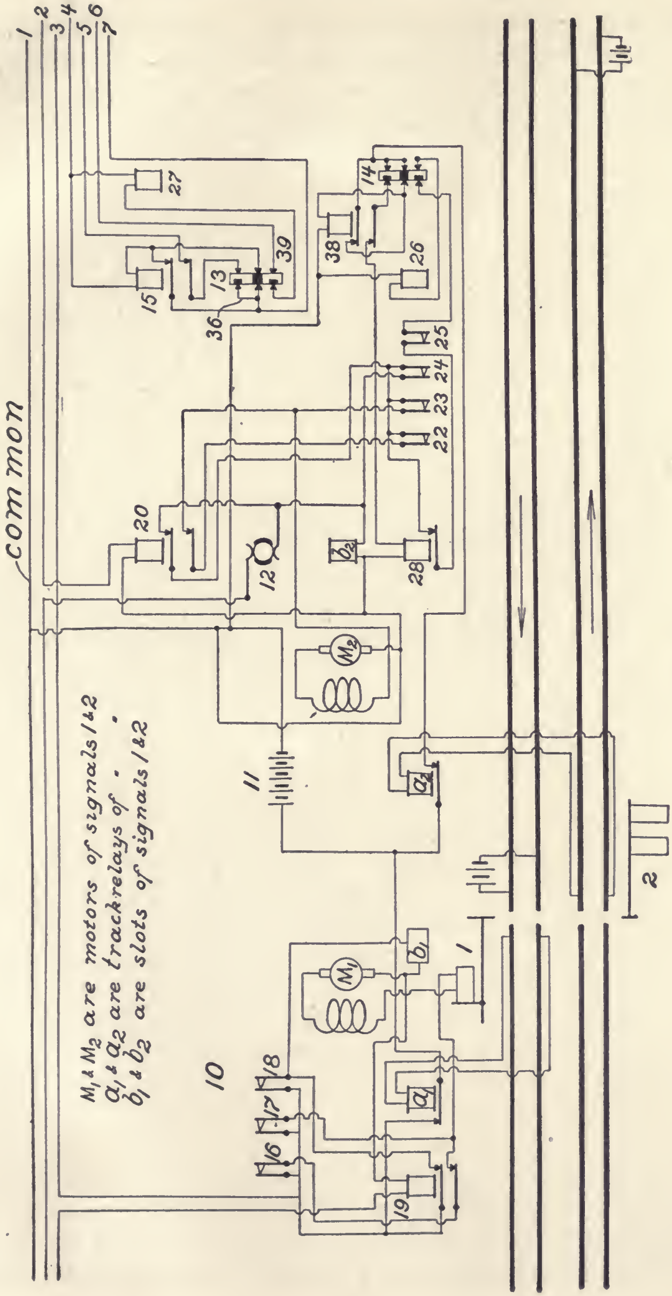

common
M_1 & M_2 are motors of signals 1 & 2
a_1 & a_2 are trackrelays of " "
b_1 & b_2 are slots of signals 1 & 2

FIG. 185

performs the office of a track relay, the motor and other circuit being closed by its armature, thus allowing the semaphore to be cleared. With a train between 1 and 4, track relay 35 is short-circuited, which open-circuits 33 and 15, thus causing 4

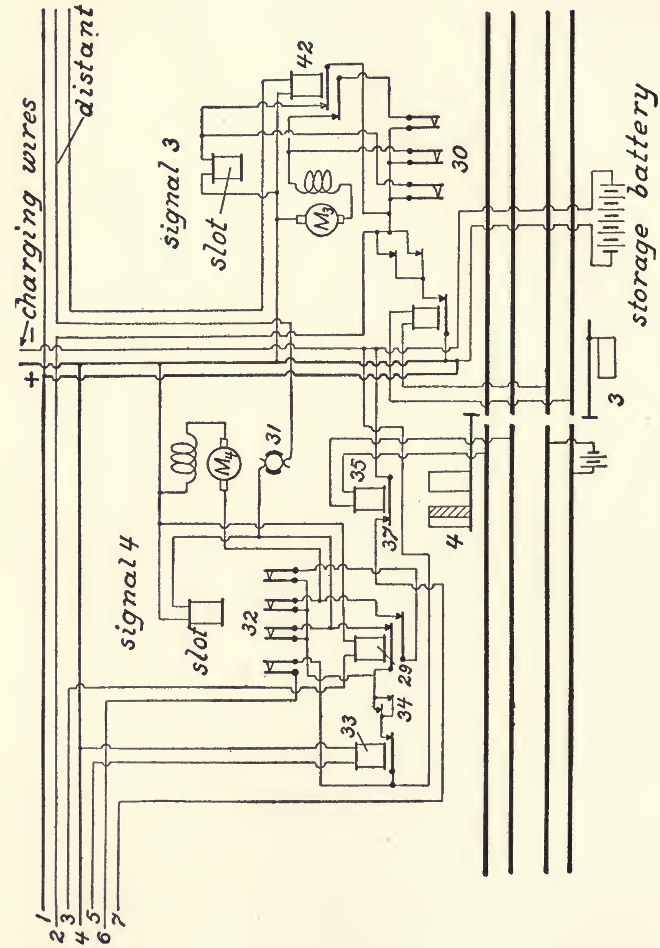


Fig. 186

to move to the stop position. When the lever of 4 is put into its normal position, 15 will be energized by reason of 36 being connected to 39 (13 and 14 are supposed to move vertically). It will be evident that these semi-automatic signals are thus

returned electrically to the stop position, and cleared mechanically.

When 33 is energized, 4 cannot be cleared unless the block ahead is clear, because of the track relay introduced; which is also the case in the automatic control of signal 1. The lever of 4 is locked in its stop position by the deënergization of the lock magnet, 27; hence the latter must have its circuit to battery closed through 39, the first left-hand set of the contacts, 32, line 6, battery, and line 4. The first set of contacts at 32 will not be closed, however, unless 4 is in the stop position.

Slot circuit-closers 32 are operated in a manner similar to the three-position contactors that have been described. With a clear track, the signalman must first clear 4 before a train can enter the block. The unlatching moves 13, and simultaneously 31, thereby throwing the signal, by sending a current from the battery through the motor circuit. The circuit closer, 31, is similar to 12, while 29 and 42 are three-position relays. The contractors, 30, are operated by signal 3; and 14 is a circuit controller, similar to 13, operated by movement of 2. The respective signal slots are b_1, b_2, etc., the track relays, a_1, etc.

In Fig. 187, the connections of three consecutive G. E. three-position signals, 75, 85, and 95, appear. Two line wires, 1 and 2, interconnect the various signals, these being in series with the three-position relays, R. The contacts of the latter are closed when the semaphore is in the clear and danger positions, and open when in the caution position. The controller, A, is an arrangement with movable sectors and stationary contacts; and rotates in an opposite sense (in the diagram) to the semaphore. The lock magnet, L, holds the semaphore in position, and the clutch magnet, C, in series with the motor, M, engages the semaphore operating gear at its various positions of rest.

When the semaphore is at clear, 7 is connected to 8, and the lock-magnet and three-position relay (at 65) are in multiple, being energized by the power battery, P, at 75. The lock magnet holds the semaphore at clear, and opposes the tendency of gravity to move it to the stop position. As R is energized, the current to the lock magnet, L, is in series with its armature.

With the semaphore at caution, 6 and 7 and 4 and 5 are connected. The three-position relay, R, at 85 is deënergized, since the track battery, T, at 95, is short-circuited. Current thus

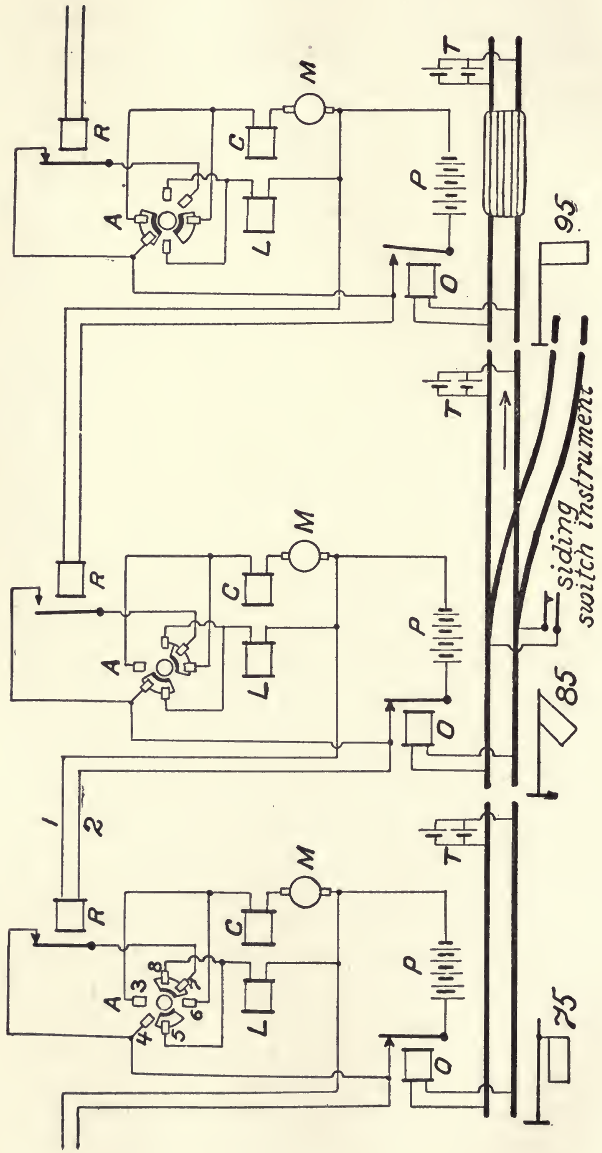


Fig. 187

passes through R (at 75) and the lock magnet in parallel, the motor, M, being out of circuit at this moment.

When the semaphore is at danger, as at 95, the track relay, O, is short-circuited, thus cutting the motor out of circuit with the power battery. The three-position lock and clutch magnets are thereby deënergized, and the semaphore is acted upon only by gravity. It should be remembered that all movements toward full clear are performed by the motor, and all toward danger by gravity. Thus the return from clear to caution is effected by gravity under the control of the lock magnet.

In Fig. 188 a later modification of the above is shown. The power battery, P, in this case is disconnected from the motor circuit by a quadruple break as are also the stationary contacts, 4 and 7, of the controller. These contacts carry the heavy working current, the actual construction being shown in Fig. 190.

One form of G. E. top post, automatic, three-position signal, such as is used in connection with signal bridges, is illustrated in Fig. 189. The glass spectacles are removed, the semaphore being in the caution position. The return to stop is assured (by reason of a preponderance of weight on the left side) after the lock magnet has released.

The internal mechanism of the top post three-position signal is shown in Fig. 190, the doors of the housing being thrown open. The small series-wound motor, M, drives the main gear, G, which is indirectly connected to the semaphore shaft. Secured to this same shaft are the contact sectors of the controller, S, which engage with fixed clips during rotation. An intermediate shaft gear and pinion exist to further decrease the motor speed. D is a dashpot, whose piston rod is connected to a crank, carried by the semaphore rock shaft, to prevent injury to the parts when the blade returns to stop. C is the lock and L the clutch magnet, whose connections were shown in Fig. 187. The stationary contacts of the controller are connected to the track-relay armatures, lock and clutch magnets, battery and lines, in the order shown in the latter circuit diagram. The clutch magnet operates a toggle clamp which holds the semaphore in its proper position.

The lock magnet is in circuit when the blade is at clear and caution, but not when in the stop position; the clutch magnet being in circuit whenever the motor is, since it is in series with

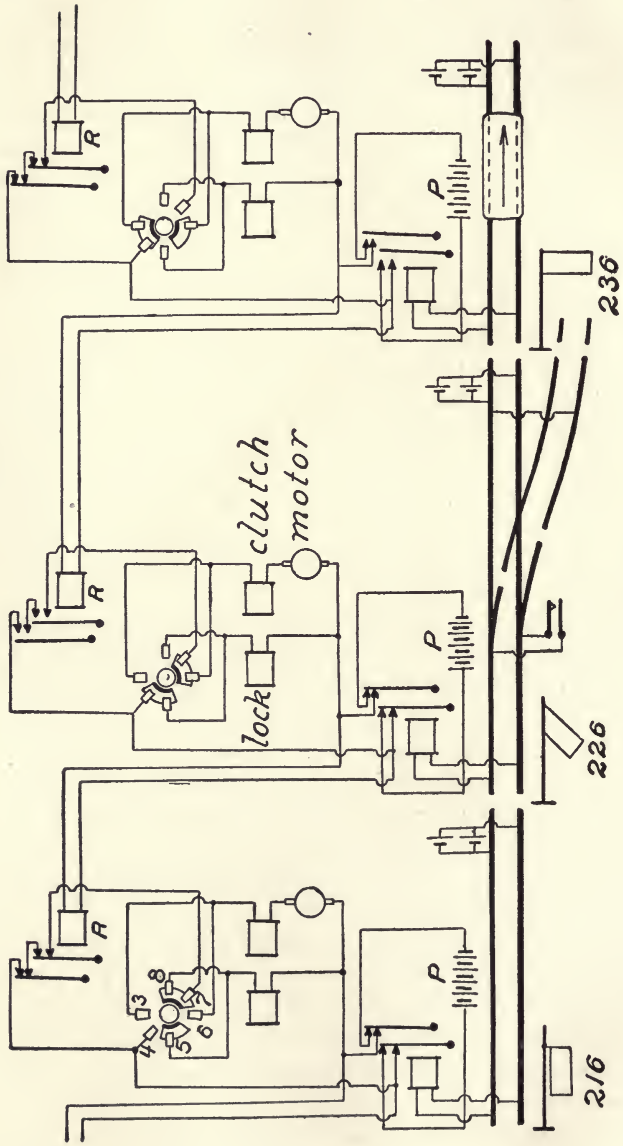


Fig. 188.

the latter. The circuit is broken by a spring action quick break, so that burning of the contacts will be minimized.

A later development of the above three-position (normal clear) operating structure, appears in Fig. 191. The 14-volt series motor, A, drives the train of gears and pinions, C, D, E, F, thereby transmitting a rotary movement to the clutch wheel, H, which is free to move on the semaphore shaft, J. The inner face

Fig. 189

of this clutch gear contains a plurality of V-shaped bosses, B, with which the clutch structure, K, engages, when the operating magnets, M–M', are energized. These magnets, with their armature and toggle levers, are mounted on a sector frame, S, which is rigidly keyed to the shaft, J, and thus gives motion to the semaphore, the latter being attached at Q. The motor and clutch magnets, as shown in the diagram, are connected in series, so that when the motor is operative, these coils are energized, thus causing the toggle levers to force the working end

into engagement with the bosses on the clutch wheel, which is then revolved in the direction of the arrow by the motor, thereby throwing the semaphore to the caution or clear direction. This locking sector, S, mounted directly on the shaft, J, is provided with bosses (not evident in the position given)

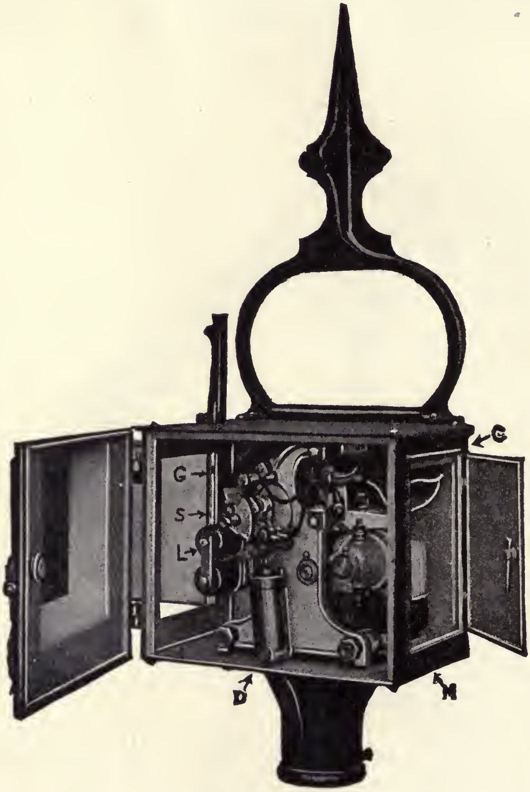


Fig. 190

which engage with, and are securely held by, the toggle levers operated by the magnets, $N-N'$, at the caution and clear positions. By the action of the control contacts, a, b (and four others at the rear of P), and the segments, U and U', the motor is thrown in and out of circuit. In the caution position $N-N'$ is energized and the lock toggles (counterweighted at O), engage with the boss on the locking sector, thus holding the semaphore

at the 45° position. With the track circuit justifying a clear indication (which is normal); a similar scheme of connections obtains, with the same sequence.

The contact segments, U, U', and U'', effect the proper variation of interconnection with the contact fingers, a, b, c, d, etc.,

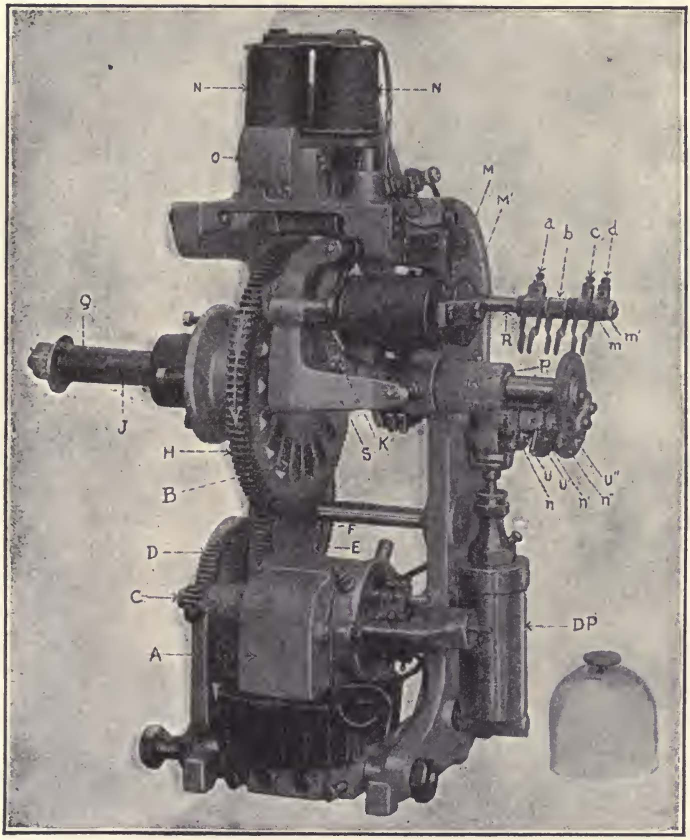


Fig. 191

and are mounted on the shaft sleeve, P (keyed to J), carrying the plunger of the oil filled dashpot, DP, and insulated by the moulded collars, n, n', and n''. The remaining connections and especially those made by the fingers and posts hidden from view, are effected as in the diagram and preceding mechanism. An additional adjustable control segment, U'', and fingers, c and

d, constitute an auxiliary control feature, for purposes of indication at a block tower or similarly appointed location.

By arranging the mechanism adjacent to the semaphore, with the rock shaft of the latter driven directly by the gearing, a remarkably self-contained unit is assured. This, in combination with the three-position arrangement, marks a step forward in the standardization of automatic signals. The energy taken by the motor is also greatly reduced, owing to the absence of clumsy connections and accessories.

The three-position Hall electro-gas signal employs two cylinders which are connected to the single signal rod by a walking beam. When the home clears, the beam is lifted at one end, the signal rod moving half its distance, the fulcrum being at the distant cylinder. When the latter clears, the end at the home cylinder is the fulcrum, the rod being thus forced to complete its stroke. About three seconds are required for clearing such a semaphore, a single cylinder moving its entire stroke in from one to two seconds.

CHAPTER XVI.

ELECTRIC RAILWAY SYSTEMS.

Electric railway signals have not as yet reached the perfection that steam road devices approach, owing to their more recent application, and the inherent difficulties obtaining in such systems which do not have to be considered in the latter case. Chief among these is the leakage current necessarily the concomitant of a grounded system in which heavy currents at high voltage are employed. This leakage is so great that ordinary battery relays become useless. An advantage, which, however, can be over-estimated, is the power circuit current that can be drawn in any quantity at every point on the right of way. Nearly all signals applied to electric lines employ a contact device operated directly or indirectly by the trolley wheel, third-rail shoe, or other part of the moving car.

On a grounded return direct-current street railway system, or on a steam road which is crossed by or interconnected through ground pipes or bridges with such a system, it sometimes becomes advantageous to use a signaling scheme which will not respond to direct current. The working circuits may be of direct current, this latter either obtained from batteries or the power lines; but the control circuits carry only alternating current. Such an arrangement is represented generically in Fig. 192, the circuits having two insulated components, one containing the secondary, *S*, of a small transformer or converter, and the other the primary coil, *P*. The track is connected to an alternating-current supply, the special laminated magnetic circuit relay, *R*, governing the elements for either a normal clear or a normal danger system. A direct current, whether by leakage or grounded connection, flowing through the primary, cannot induce a current in the secondary or, consequently, operate the signal.

In the New York Subway, but one track is divided into insulated sections, the signals, lamps, and relays being operated by alternating current, these relays having vanes instead of arma-

tures to close the contacts. Several other such systems have been devised and applied, but not to an extent that would warrant their description herein.

On an alternating-current road, the relays can be made of high ohmic impedance, so that an alternating current cannot set up sufficient current in the coils to lift the armature. Direct current is of course used in both supply and control circuits, since the opposing inductance of the relays is but momentary, and manifested only when a change in current strength occurs.

Fig. 193 is a diagram showing the circuit arrangement used in the Uni direct-current system. The trolley wheel, *T*, operates a special switch, *L*, and closes a circuit according to the direction of motion. *I* is a lightning arrester in series with the permanent feed-wire, *M*. The latter is connected to a red lamp, *F*, the locking electromagnet, *A*, the contacts, *E*, operated by *B*, the contact, *D*, lightning arrester *K*, lighting line-wire *R*, and to ground, through similar apparatus at *N*. *B* and *C* are the

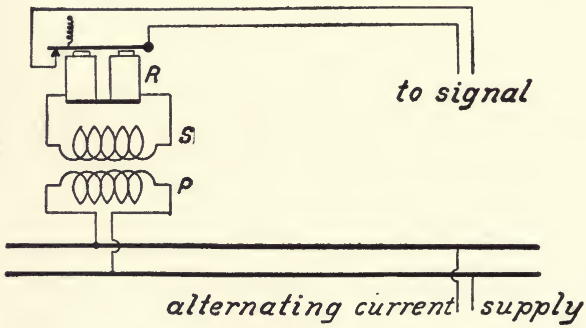


FIG. 192

lighting magnets, since when they are energized the lamps are lighted. These are alternately excited, the cores acting upon a walking beam. In the position shown, the green lamp, *G*, is energized, while in the opposite position, *F* will be in circuit. The extinguishing line-wire, *S*, is in series with *B*, through the lightning arrester, *J*, and the trolley switch, *L*, or the switch contacts, *O*, operated by *C*. *H* is a resistance interposed in the power circuit to keep the current down to the required figure. *A* operates the contacts, *P*, and locks the arrangement, preventing interference.

When a car enters the block, the automatic switch is struck by the trolley, thus lighting the green lamp at the home end of the block, at the same time lighting the red lamp at the distant end; the latter being in series with the former. When the car reaches the trolley switch at the leaving or distant end of the block, both lamps are extinguished. The block is thus unoccupied when both lamps are out, and occupied when either red lamp is in circuit. Since the arrangement is double acting, this applies to cars entering either section. The current carried under any condition is one-half ampere.

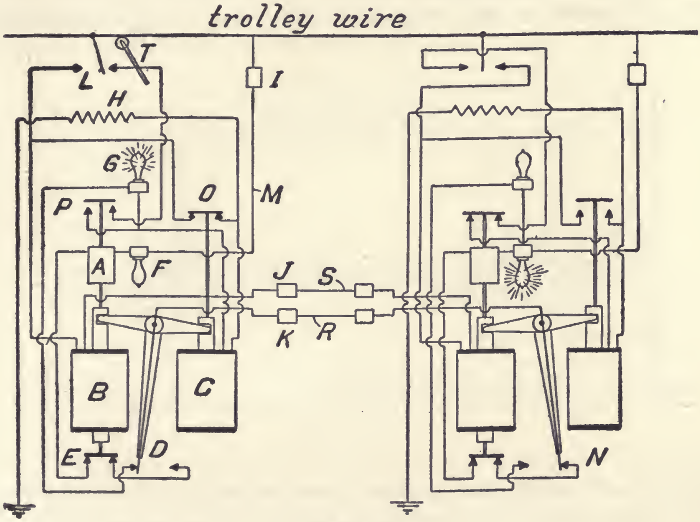


FIG. 193

Unless a car receives a green signal on approaching a block, that block is in a dangerous condition. A car following one already occupying the block does not affect the signal circuits set up by the former, and a visual indication will not be given to either should a lamp burn out. The latter is a remote possibility, since they are renewed monthly.

The single-wire circuit arrangement used in conjunction with the Eureka system, is shown in Fig. 194. *G* is a contact maker, consisting of steel combs having contact teeth, connected on one side to the feed wire and to the rail or ground through the electromagnet, *M*, and the resistance, *R*. The lamps, *L*, are

shunted by the resistances, *S*, so that should any burn out the remainder will still give visual indication. *M* operates a contact arrangement consisting of a rotating structure carrying contact fingers *A*, which engage with contacts *P*, *O*, and *N*, according to the position of the mechanism. A similar combination is used at *B*. When, as shown in the figure, the lamps, *L*, are burning, it indicates that the block is occupied. When this does not occur, the lamps are either connected to the feed wire, or to ground only. But one car at a time can thus occupy a block.

In the two-wire system, a diagram of which is given in Fig. 195, a number of cars can be in the block at the same time.

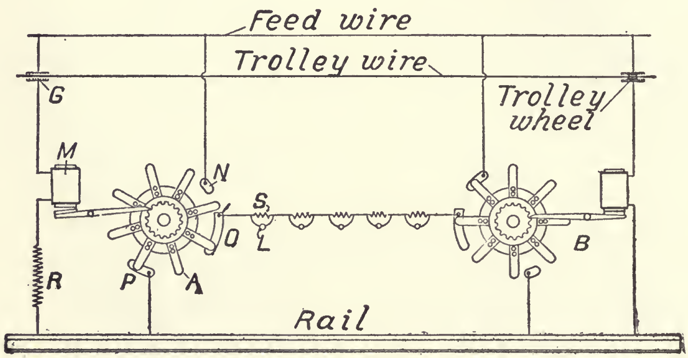


FIG. 194

The contact comb in this case has three members, a long comb on one side of the trolley wire, and two short ones on the opposite side. The main-current controller, *G*, has two electromagnets, *F* and *E*, which act independently upon the rotating member.

When a car enters the block, the current passes from the short comb the wheel comes first in contact with, sending current through the setting magnets and holding the signals at danger. One of the magnets actuates an automatic switch, so that the current passes through the same coil when the second short comb is struck. *C* and *D* constitute a current-directing relay whose function, as above stated, is to keep the current from both short combs flowing through the same magnet, when the trolley wheel strikes the contact maker. When a car enters the block it switches the current from both combs through the operating

magnets, setting the system at danger; and when the car leaves the block it similarly sets the system at safety. This occurs in both directions.

Under normal operative conditions, the circuit of an empty block is grounded at both ends. This circuit, as above shown, consists of four green lamps, *g*, in series with a red lamp, *r*, at either end of the block. The controller, *I*, is similar in construction to *G*; the auxiliary controller, *H*, being interposed, whose function it is to open or close the magnet-operating circuit. Should two cars enter the block from opposite ends, this latter opens the circuit automatically, so that one car must back out of the block, thereby restoring the apparatus, and giving the

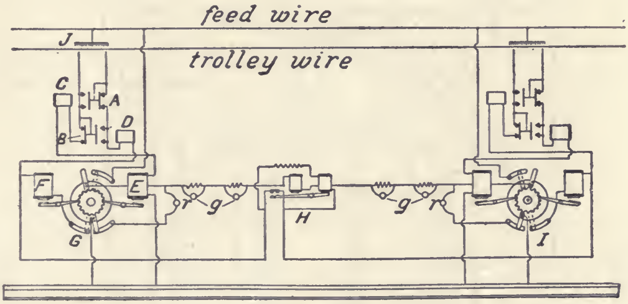


FIG. 195

other car the right of way. When a car enters an unoccupied block, *H* closes the circuit, so that when the car leaves the block at the other end the main controller first energized is again energized, thus restoring the circuits to their normal condition. This device may be dispensed with, but it makes a more effective and desirable combination.

The United States system employs pivoted disks or "semaphores" in addition to lamps, these semaphores being operated by magnets. A mechanical locking device also secures the contacts until released by the car's leaving the block. In Fig. 196, the internal circuits at each end of the block are shown; and in Fig. 197, the external circuits of the entire block. Since but two lamps are normally in circuit at the same time, resistances *R* are interposed to keep down the current. When a car enters the left-hand (or setting) end, the wheel closes the right-hand side of the trolley switch; the current thereby flowing

through the magnet, *B*, line 3, to the other signal and ground. When *B* is energized, it throws over its contact lever, thus dis-

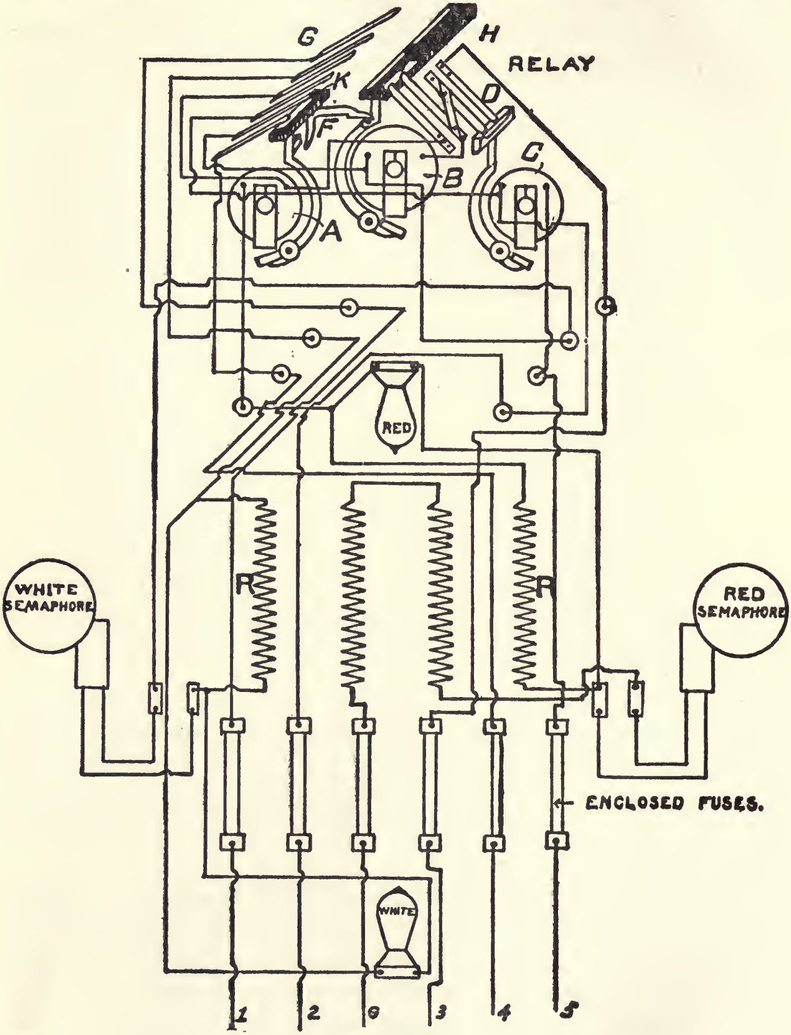


Fig. 196

connecting the ground wire, and putting the feed from the trolley wire into circuit, the trolley switch contact opening immediately after the car has passed. The green lamp is then

illuminated and its semaphore thrown, thus indicating that the red lamp and semaphore have been set at the other end of the block. The remaining contacts closed by the movement of the armature of *B* close a circuit including the outside contact of both trolley switches. The magnet, *A*, is in series with the signaling circuit, and opens two non-interference contacts in series with the trolley switch, thus preventing a car from entering at the opposite end of the block, locking the lever of the magnet, *B*, at this end, making a normal indication until the car passes out of this end of the block. Line 2 and its connections constitute a releasing circuit. Upon the car passing out of the block, it operates the outbound trolley switch, closing the right hand

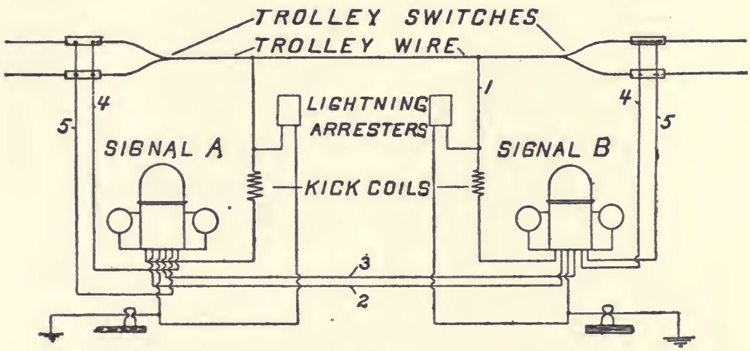


Fig. 197

contacts, sending a current through *C* at this end of the block, thus breaking the signaling circuits and that of magnet *A* through the contacts of the latter's armature; and unlocking the armature of *B* by releasing lock piece *F*. Since *B* is deënergized, the apparatus is again in its normal condition. The above sequence of connections occurs with a car moving in either direction. The actual arrangement of the contact carrying members *H* and *K*, and of the stationary contacts, *G* and *D*, is not as shown in the figure, where an attempt is made only to show the principle.

In the Kinsman system, a remote modification of which is used on the Boston Elevated and Interborough Rapid Transit Railroads (electric, although it is equally well adapted to steam roads), an automatic train-stop is employed in conjunction with a manual or automatic visual system in such a way that the control of the

train is taken from the engineman or motorman at a critical time, so that it is not possible to pass a danger signal. This arrangement meets the demand for a device which, independently of the motorman or engineman, would set up a retarding effect, preventing procedure into an occupied or otherwise dangerous block.

Fig. 198 shows the above applied to a normal clear automatic visual system. The home and distant semaphore signal, *S*, has its home control magnet equipped with an auxiliary armature, *m*, which has a front and back contact, and is in series with a switch box, *E*, the slightly elevated guard or contact rails, *G*, and the battery, *B*. These contact rails are each about 120 feet in length, with inwardly curved ends. The battery, *B*, is in two parts; one side having a voltage of about 5, and the other side 3. The front contact of *m* is connected to the junction of these parts, so that when it is in the upper position, the voltage impressed on the circuit will be 3, and in the lower position, 8.

Two contact arms, *K*, are fastened to, and insulated from, the locomotive; these making a scraping contact with the guard rails. Connected to these contact pieces and the engine or car frame is a circuit containing an electrical recording device, *H*, and a stop magnet, *J*, the latter operating directly on the throttle (or control switch, controller, or circuit breaker of an electric train), or being so interposed that it forms a positive link between the throttle and valve. Simultaneously with the shutting off of the steam or current, the air brake is applied.

Returning to Fig. 198, if a train, represented by the locomotive equipment, *H–K*, be moving in an easterly direction with a dangerous track (having the switch *A* open), and consequently with the signal in the danger or stop position; as soon as the contact arms strike the guard rails, a current passes from all of *B* through *m*, to the switch box, guard rails, stop-valve magnet, and returns through the frame of the engine and rail. The stop-valve shuts off the steam, applies the air brake, and, by raising its armature, closes the circuit of the danger-recording magnet, *H*1. This stop-valve magnet requires from 5 to 8 volts at its terminals to operate. At signals *C* and *D*, the same connections obtain. The key switch-box is in series with *m*, so that when the brakeman turns the key, the control circuit will be opened.

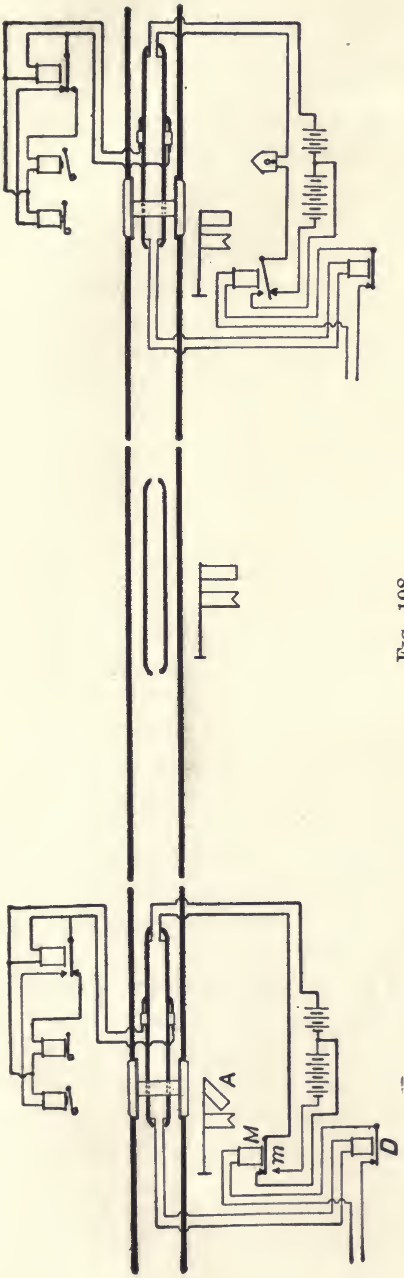


Fig. 198

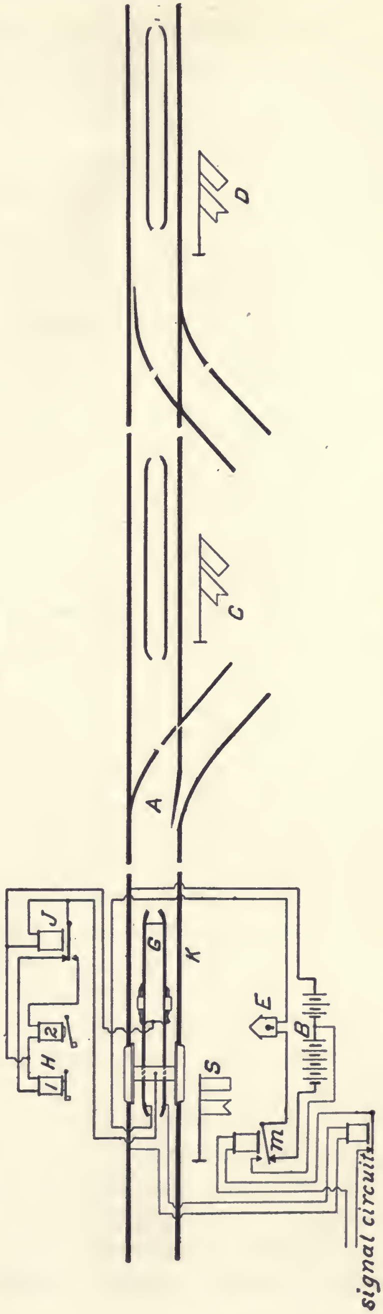


Fig. 199

If the switch at *A* were closed, the visual signal would be in the clear position, hence *m* would close its front contact. This would send a current at a potential of 3 volts through the same circuit, but the stop-valve magnet would not operate. Its armature therefore remains in the lower position, thus causing a current to pass through the safety recording magnet, *H*2.

In Fig. 199 the application to a normal danger system is shown. A train is supposed to be in the distant block of signal *A*, the home block being clear. The current passing through the home magnet, *M*, by way of the armature of the relay, *D*, raises *m* and causes a current to flow through the circuit shown by the heavy lines. Thus the action of the apparatus is similar to that shown in the diagram for normal clear circuits. The current through the recording apparatus is therefore the same in both cases. The latter is not a required part of the arrangement, but its use is advisable, since it serves as a check upon the engineman's statements.

In order that a switching engine may make reverse movements at a signal, the circuit is opened at the switch box, which prevents the signal apparatus from operating. In order to prevent failures in this apparatus from causing disastrous results, a detector circuit is employed, the relay, *D*, being in this circuit, which is normally closed. A broken wire, open or exhausted battery, or other defective condition, will open the circuit at this point, and throw the home signal to the danger position. This will also cause the stop magnet to operate if the train passes the stop signal. If at the same time a failure manifests itself in the locomotive and contact-rail equipments, then disaster may accrue. But the probability of such coincidence events occurring is remote.

The obvious advantages of the Kinsman system are somewhat offset by the necessity of adding parts to a car or locomotive, in opening the circuit at switching movements, the use of contact rails, and the poor protection afforded to a slow-moving freight train pushed by an engine at its rear. An automatic stop, nevertheless, removes one of the greatest disadvantages of visual signaling devices.

A difficulty encountered in a grounded-return system is the disproportionate current carried by the track rails, which is

moreover continually varying in value, due to the greater or less conductive continuity outside of the rails, and the uncertainty of the contact of the car wheels therewith. In one system this effect is overcome by making each section a conducting loop with heavy stranded inductive bonds at the insulating joints, which are electrically joined at their adjacent centers. A low-potential transformer secondary with or without an air-gap in the magnetic circuit supplies energy to the section and relays.

Until proper commercial development has occurred it would be out of place to include a description of such devices, however meritorious they might appear, although several such are being considered by a number of trunk lines.

CHAPTER XVII.

MAINTENANCE.

The operation of cleaning the zinc and removing part of the more or less saturated zinc sulphate solution from a gravity cell is known as patching. Owing to the impurities which occur in commercial zinc, this element becomes coated to a depth of one-half inch or so with an adhesive brown or gray mass, after about two weeks of ordinary continuous operation. This latter must be removed at regular intervals, or it will interfere with the proper circulation of the liquids, and consequently with the operation of the cell. The lower projections of this deposit may either come into direct contact with the copper or with the copper sulphate solution, either of which will produce a partial short-circuit of the cell.

This mass is removed most expeditiously by a dull knife, after which a long-handled brush with short stiff bristles is used to clean the zinc thoroughly. This may be repeated until but a small amount of zinc remains, when a new element must be used. It is never advisable to leave too little or just enough zinc for the last run, as such a proceeding may result in either complete inoperation before the proper time, or, by setting up too weak a current, produce an unreliable movement of the track-relay armature. Although failure of the armature to lift can only hold the signal to which it is connected at the danger position, this entails an unnecessary loss of time to passing trains.

Alternating with the operation of patching is that of renewing. The liquids of the cell are thrown away, excepting about one quart of the zinc sulphate solution, which is retained and furnishes the initial sulphuric acid for the renewed cell. The zinc and copper are cleaned of their deposits, and the undissolved crystals of bluestone saved. Two pounds of new bluestone are added, and after the quart of old solution has been replaced, the cell is filled to the proper height with clean water. Renew-

ing is a wasteful process, but it has not been found practicable to save the saturated copper sulphate solution. The scraps of copper, however, are returned to the supply house. Patching and renewing are performed each month, so that the battery-man goes over his territory every two weeks. This territory, on a double-track road, may be of from 15 to 30 miles in length.

All joints in the wiring of a signal system must be soldered. The best way of accomplishing this is by means of molten solder in a crucible or pot, which is poured over the cleaned and fluxed joint by a ladle. All traces of flux are thus removed, and a thoroughly heated joint with a minimum amount of superfluous solder results. After being soldered, the joint is

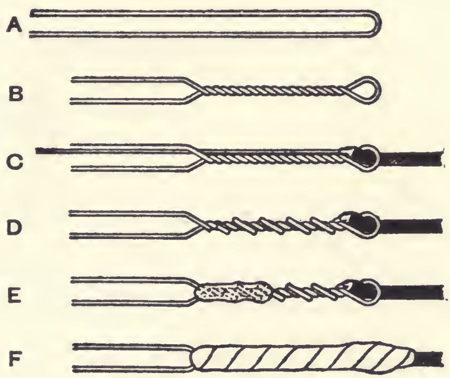


Fig. 200

carefully taped, preferably first with rubber strip, the latter being covered with a thin layer of binding tape. The finishing consists in either gently heating the joint, or painting with a quick drying waterproof solution.

The proper joining of copper conductors to the steel rail is a matter of primary importance, a certain amount of skill being required. In Fig. 200, *A* is the formed iron wire end which is to be connected to the rail by channel pins or plugs, for either a relay, controller, or battery connection. At *B* the wire is twisted, which constitutes the second step, and *C* shows an insulated copper wire inserted in the loop, the insulation being removed from the loop to the end. This wire is twisted around the iron, forming *D*, after which it is soldered, as at *E*, near the

end of the joint, so that the insulation will remain uninjured. After making sure that not a trace of flux remains, the joint is taped carefully, as shown at *F*.

The manner of connecting and housing such a taped joint is shown in Fig. 201. *A* gives a section of the rail and an end view of the wood trunking or duct; *B* is a longitudinal section, and *C* an elevation. The weather cap, *D*, is shown removed at *B*.

Track batteries should be frequently and carefully inspected to determine not only their physical condition, but their electrical performance when operating. Faulty or dirty connections may result in the addition of considerable resistance.

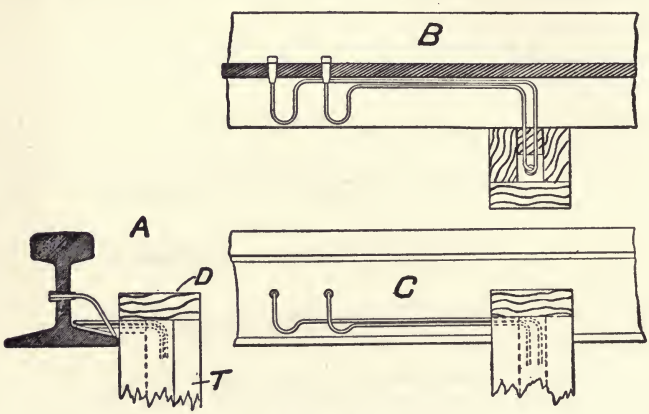


FIG. 201

Thus, in taking a millivoltmeter reading across the cells, and at the track, if even a slight difference occurs, a high resistance may occur between these two points. This may be due to faulty connections, too much or too fine wire, and, in some cases, imperfect contacts at the pole-changing switch.

A relay which fails to close its armature circuit with its minimum current should be at once replaced, and contacts that have been fused by lightning and then separated should be discarded. When track sections are inspected, the bonding, insulating joints, condition of the ballast, rail connections, and line wires should also be given attention. It is well to make memoranda of everything noted, so that local operative conditions may be deduced from the data thus obtained. The

numbers of all cut-sections and signals should be tabulated, thus systematizing the entire territory.

When a battery reading is obtained at one end of a section, it should be compared with the reading at the other end of this section. Either may be the battery or relay ends, depending upon the direction taken. Proper drainage of the roadbed must be insisted upon; and the relative amount of moisture present may be found by these readings.

In hot weather the expansion of the rails may force the fiber rail-ends slightly above the level of the rail face. Passing trains then pound off this projecting piece, ultimately destroying the fiber, and sometimes causing the upset parts of the rail to come into contact. This results in one side of the adjacent

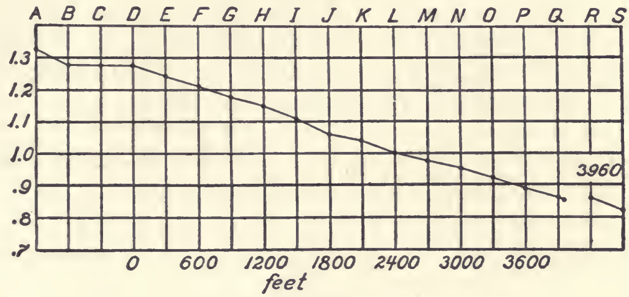


Fig. 202

sections being connected, interfering with the normal operation of the system This is a condition that is difficult to remedy, and replacing of the rail end must ultimately be resorted to.

In Fig. 202 (which shows one square for each one hundred in the original), the voltmeter readings obtained from a typical wireless cut-section have been plotted. The cross-section paper on which the results are given should allow one vertical division for each one-hundredth of a volt, or 100 divisions per volt. Each horizontal division may be equivalent to one rail length, or 30 feet, there being $\frac{5280}{30} = 176$ divisions per mile of track. The voltage curve is found by joining the points of intersection of the voltage reading obtained at each ten-rail section with the horizontal equivalent of the number of rail lengths from the

starting point. The voltage is measured at each change in connections. At *A* we have the voltage at the battery terminals; *B* is the voltage at the terminals of the polarity changer; *C* at the connection of the pole-changing switch with the track wires; *D* the voltage between the rails; *E* to *Q*, inclusive, the voltage at the various equidistant divisions; *Q* that at the last rail length considered (No. 132, or 3960 feet from *D*); and *R* and *S* that at the end of the rails and terminals of the track relay respectively. The reason for the line, *D-Q*, not being straight is because of the different effects introduced by the heterogeneous conditions of the ties, unequal depth of ballast, non-uniform resistance of bond wires, and various specific rail resistances; although this curve may be taken as being sufficiently uniform to show good practice. The current taken by the relay (.62 ampere) was too slight to introduce any perceptible temperature effect. With a battery voltage of 1.32 the following readings are apparent from the curve at the various points where measurement was taken.

Voltage at		*Volts*
A, or battery terminals		1.32
B, or pole changer terminals		1.32
C, or track wires		1.32
D, or between rails		1.28
E, or between rails at	10 rail lengths	1.25
F, or between rails at	20 rail lengths	1.21
G, or between rails at	30 rail lengths	1.18
H, or between rails at	40 rail lengths	1.15
I, or between rails at	50 rail lengths	1.10
J, or between rails at	60 rail lengths	1.06
K, or between rails at	70 rail lengths	1.03
L, or between rails at	80 rail lengths	1.00
M, or between rails at	90 rail lengths	.98
N, or between rails at	100 rail lengths	.95
O, or between rails at	110 rail lengths	.92
P, or between rails at	120 rail lengths	.89
Q, or between rails at	130 rail lengths	.86
R, or pole changer at	132 rail lengths	.84
S, or track relay at	132 rail lengths	.82

Should abrupt changes occur in the direction of such a curve, it indicates that conditions at this point are abnormal. Thus, a high-resistance bond wire, or poor joints in a series of rail

lengths will result in a line which does not conform to the general direction of the remainder of the line. Theoretically, the line joining the points at which indications are taken should be straight, but the factors above mentioned introduce variations of direction. Should considerable current leakage occur, the change in the direction of the line would be at once evident. The curve given is a fair example of what may be expected with gravel ballast, with a relay of 3 1-2 ohms resistance, which requires a minimum of .23 volts to lift its armature. This condition gives a wide possible variation of voltage through which the armature will rise, which is necessary, because of variations in the weather conditions. On account of the decrease in the length of air-gap, and the consequent increase in the permeability caused by the motion of an armature, it follows that the minimum voltages that commence motion will produce a good closing of the contacts.

The voltage of the relay being .82 and its resistance 3.5 ohms, the current flowing through it will be .82 ÷ 3.5 or .234 ampere. As the output of the battery is .62 ampere, the relay evidently takes only a fraction of the total current, or 38 per cent; the remainder, 62 per cent, being shunted across the rails by the ballast and timbers, which represents an average percentage of leakage, the drops in potential in the rail being also considered.

Where cinders or culm are intermixed with gravel, or when the former are used exclusively as ballast, a material change in the readings obtained will be evident. This is due to the better conducting qualities of the former and to the better contact usually made with the rail. Fig. 203 illustrates an average of such cases. A battery of six gravity cells, connected in multiple, was used in this case, the current passing to the rails being one ampere, *A* being the voltage at the battery and *B* at the track. From *B* to *M* are measurements taken at regular intervals of 600 feet (20 rail lengths), the section being 7020 feet in length, *N* being the track voltage at the end of the section, and .35 the voltage at the relay.

The relay resistance is 3.5 ohms, with a terminal e.m.f. of .35 volts, the current taken being .35 ÷ 3.5 or .1 ampere, the remaining .9 ampere or 90 per cent leakage through the ballast from rail to rail.

This represents a case where failure of the relay to operate

may be expected in wet weather, owing to the better conducting qualities of the ballast at such times. Since .35 volt is just above the operating e.m.f. or such a relay, the reason for such failure is obvious.

The conditions above represented may be eliminated by shortening the length of the section, or by dividing it into a number of sections. If we divide it into two equal parts, and use two sets of batteries and relays, the length of each section will be 3510 feet, the e.m.f. at the end of the first section will be (from the curve) about .51 volt, or 46 per cent above .35 volt.

Since a greater relative gain is made by excluding some of the loss due to the track leakage, the actual result will be some-

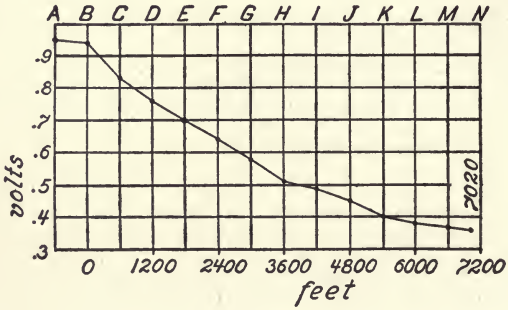


Fig. 203

what in excess to the above. It should be remembered that a track section must be designed to give a maximum of voltage at the relay, with a minimum of leakage, so that a minimum number of track cells in multiple is required. Because of the great variations in the resistance and insulation of a track section, it is not possible to give a fixed rule as to the voltage that should be maintained at the terminals of a relay.

Numerous multiple paths are afforded, even under favorable conditions, for leakage from rail to rail. For this reason the voltage across the latter must be very low, otherwise the percentage of lost energy will be too high. This voltage, however, could not be excessively low (as for instance that which would be obtained from a few thermoelectric couples in series) or relays could not be satisfactorily operated, and the shunting

action of a train in a long section might not remove sufficient current from such a relay's coils. Ties are of hard wood of high specific resistance, but since from ten to twenty-five thousand spikes are driven in them to the mile, it is seen that the reduction in insulation resistance becomes very great indeed. Particularly is this true when the ties are wet and slate or culm ballast is used. The latter frequently contains considerable sulphuric acid, which, by associating with the water, greatly reduces the specific resistance of the ballast.

With properly designed relays and other current-taking devices a larger number of cells should preferably be used in the main battery than is required under normal conditions. This is because the cells ordinarily used are more efficient when a moderate current is taken from them. Abnormal current discharge results in polarization (with concomitant increase of resistance, loss of energy, and reverse e.m.f.), sluggishness of chemical action, and poor recuperation, while the ampere-hour capacity is greatly reduced.

In winter, cells have to withstand long-continued low temperature, which decreases their terminal voltage somewhat, and increases their terminal resistance. The drop in potential in a battery is thus much greater when low temperatures obtain, so that the load upon them is increased, especially when motors are in circuit. Motors require heavy initial current discharge, so that the voltage falls very rapidly when they are in circuit. High voltage thus becomes desirable in a signal circuit, and is more than compensated for in economy of operation. Another argument for high voltage is the liability of a low potential not overcoming the resistance under the motor brushes which a particle of dirt, congealed lubricant, or moisture interposes.

To find the insulation resistance of any circuit, as, for instance, that between the rails of a track section, having given a voltmeter whose resistance is known, connect the latter in series with the resistance to be measured, and a battery whose voltage is approximately equal to the range of the voltmeter scale. After noting the reading, measure the battery voltage. Divide this latter result by the former, and add one to the quotient, which, when multiplied by the voltmeter resistance gives the required resistance. Thus with a battery reading of 2.8 volts,

and a resistance reading of .9 volt with a voltmeter resistance of 200 ohms, the unknown resistance will be $\left(\frac{2.8}{.9}+1\right)\times 200=822$ ohms.

The slot and slow-releasing magnets of a normal clear two-arm semaphore signal, with a working battery of 16 cells (11.2 volts) require a current of 16 milliamperes (.016 ampere). These three magnets, which are connected in multiple with the battery, have a combined resistance of 700 ohms, and have sometimes equal resistances, or about 2100 ohms each. The total current required per day (assuming that the semaphores remain at clear) is, therefore, .384 ampere-hour. The average motor current required is two amperes, the actual current being greater when the motor starts, and less when full speed is reached, due to the full counter e.m.f. which is developed in the latter case.

With 100 train movements a day, both semaphores would operate 100 times, so that the motor actually operates 200 times. With trains in the block for say three minutes each, the slot magnets would not be energized for 300 minutes out of each day, or 5 hours. The daily current discharge into the slot and slow-releasing magnets is thus only .304 ampere-hour. There can be eight blade movements per minute of motor operation, so that the motor will be in use for 25 minutes a day, or .416 hour, the current required being .932 ampere-hour, which, added to the .304 ampere-hours required for the slots, etc., gives 1.236 ampere-hours. As the capacity of the cells used is ordinarily 300 ampere-hours, they will last when operating this signal for about 240 days, allowing for some depreciation.

When a smaller number of train movements occur the cells will last longer. One-arm signals could be relied on to give a battery life of from one to two years, the latter being in extreme cases, as the best of cells cannot be left on an intermittent circuit for so long a time and be depended upon. The resistances of the compound slot magnets of a signal can have high values, owing to the heavy series winding which carries the motor current when the latter is operating, and thus compensate for the drop in potential due to the momentary heavy demand on the battery.

Maintainers and inspectors will find a voltmeter having two scales desirable: one reading up to three volts, and having fifty

divisions per volt; and the other reading up to 15 volts with ten divisions per volt. With the former it is possible to read, with some show of accuracy, in millivolts. A milliammeter is also a useful prerequisite to check up the resistances and input of relays and other magnets.

Motor brushes should be adjusted to exert only such pressure upon the commutator as is consistant with good electrical contact. The ends or leaves should be spread apart, to avoid the introduction of an open circuit by contact only with one of the mica strips separating the bars.

The buffers or dashpots on motor signals should receive careful attention, otherwise injury will result to the moving system or too great a retardation will occur. The vent should be so adjusted that the loss of speed (resulting on the tendency to form a vacuum) when clearing is imperceptible. In lubricating, heavy oil must not be used and care should be taken that dust or dirt does not enter the buffer chamber. A light non-freezing oil is best for use on all moving parts, including the motor commutator, it being sparingly applied on the latter by a cloth. When a signal is in the danger position all the weight of the moving system should be borne by the spectacle casting and its stop. On no account should the slot be impeded in any way.

The clearing of a semaphore by a motor is a rather tedious process, from six seconds to a quarter of a minute being required. With a two-arm arrangement, the motor must start up twice when the distant and home are cleared in the proper sequence after a train has passed a signal.

Relay boxes must be of such construction that insects cannot enter, as their operation sometimes causes open circuits or false conditions. They must also be weatherproof, although extreme care need not be exercised, providing the relays are enclosed in glass covers, which is the present practice in construction. Motor armatures should also be well protected, particularly at the commutator end, as a trifling amount of dirt at this part may cause endless trouble. Although an open circuit in the motor can only result in a false danger indication, this produces a certain amount of delay to through trains. All operated contacts must be enclosed in closed housings to prevent access of moisture or dust.

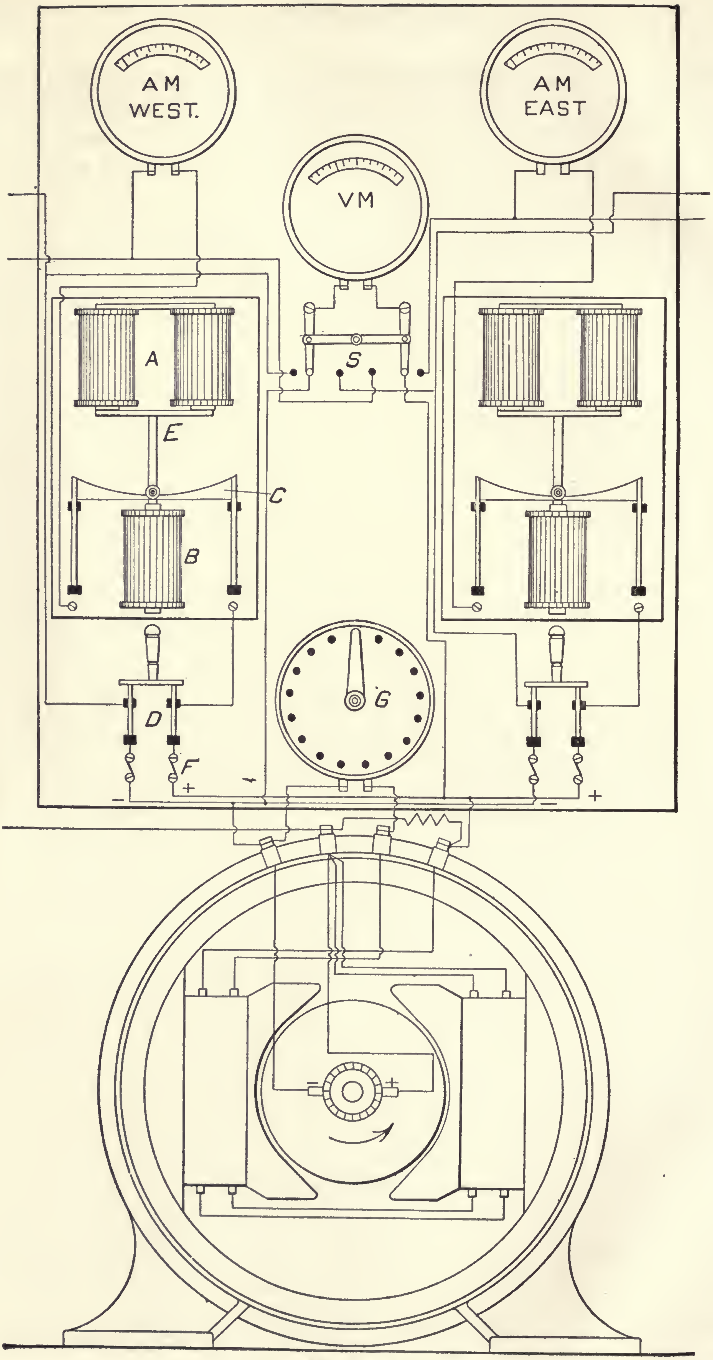


Fig. 204

Engineers or conductors are generally requested to fill out blanks when held by a signal for which the immediate cause is unknown. These are passed to the maintainer or inspector, whose duty is to at once examine the signals and accessories to determine the cause of failure. Maintainers, batterymen, supervisors, and engineers, with the maintenance-of-way corps, exercise such a strict observance of the working conditions that it is not often a failure takes place undetected. Such constant supervision, particularly on roads having heavy traffic, is absolutely necessary to keep up the integrity of a signal system.

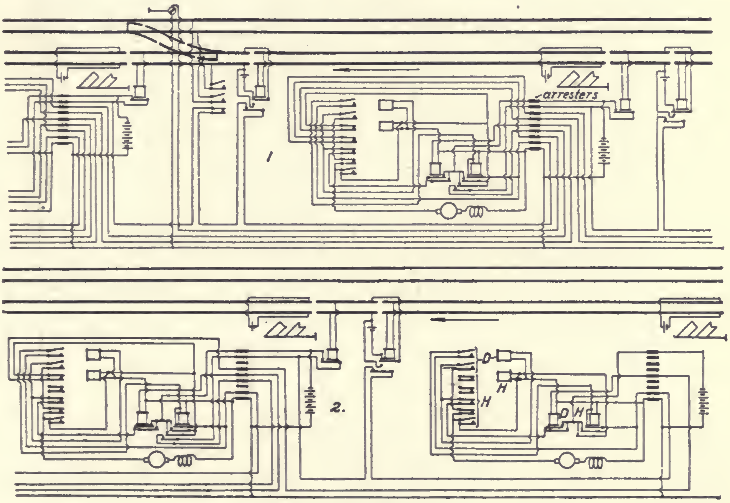
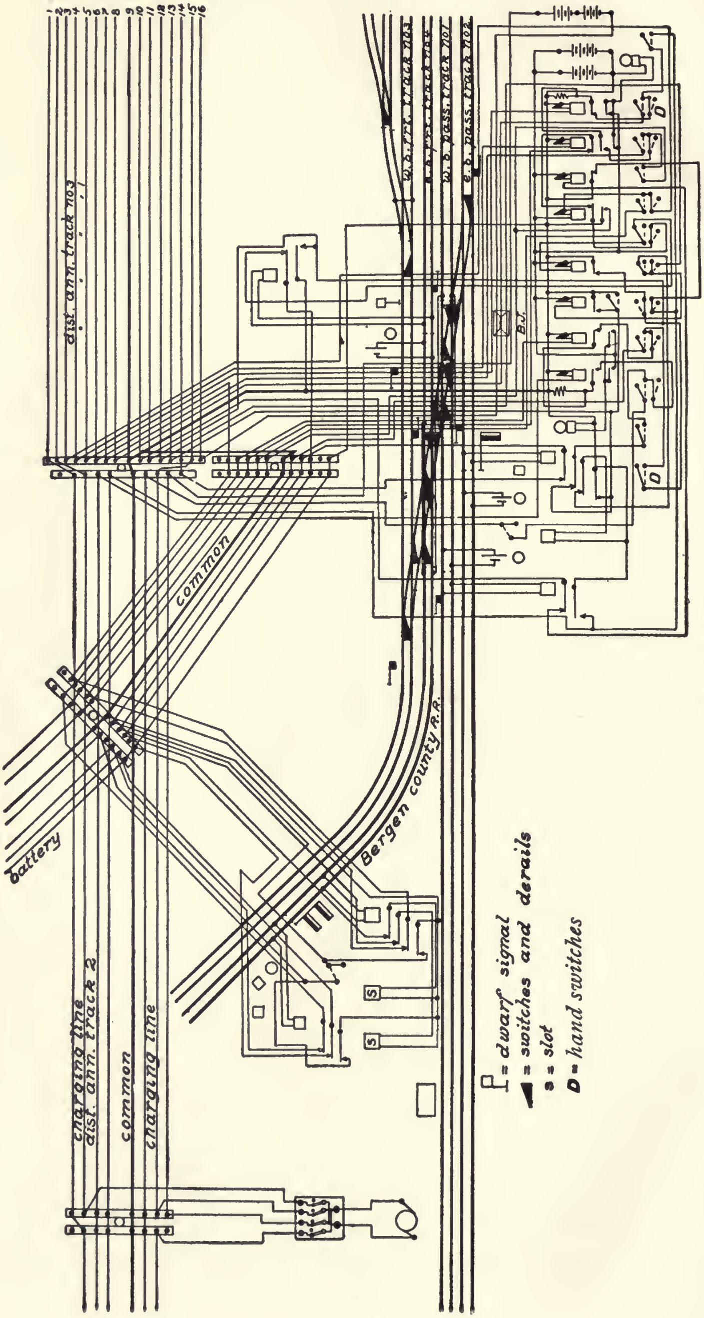


Fig. 205

When any serious trouble occurs, its results increase with great rapidity, owing to the momentous position which signals possess in a competent aggrandization. Maintainers must go over their entire territory immediately subsequent to a lightning storm, replacing fuses and inspecting relay points. Special engines are delegated to assist in performing this service, a flurry of telegrams and messages being coincident.

Continuous spectacles and castings are advancing in favor, and are meritorious because they prevent a clear indication until the semaphore has described more than two-thirds of its working arc, also eliminating the complete shutting off of the



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
dist. ann. track no 3
w.b. frt. track no 3
e.b. frt. track no 4
w.b. pass. track no 1
e.b. pass. track no 2
B.J.
D
common
battery
Bergen county R.R.
charging line
dist. ann. track 2
common
charging line
= dwarf signal
= switches and derails
s = slot
D = hand switches

FIG. 206

light at any point or angle of transition when moving for an indication. A drooping semaphore may readily be detected in

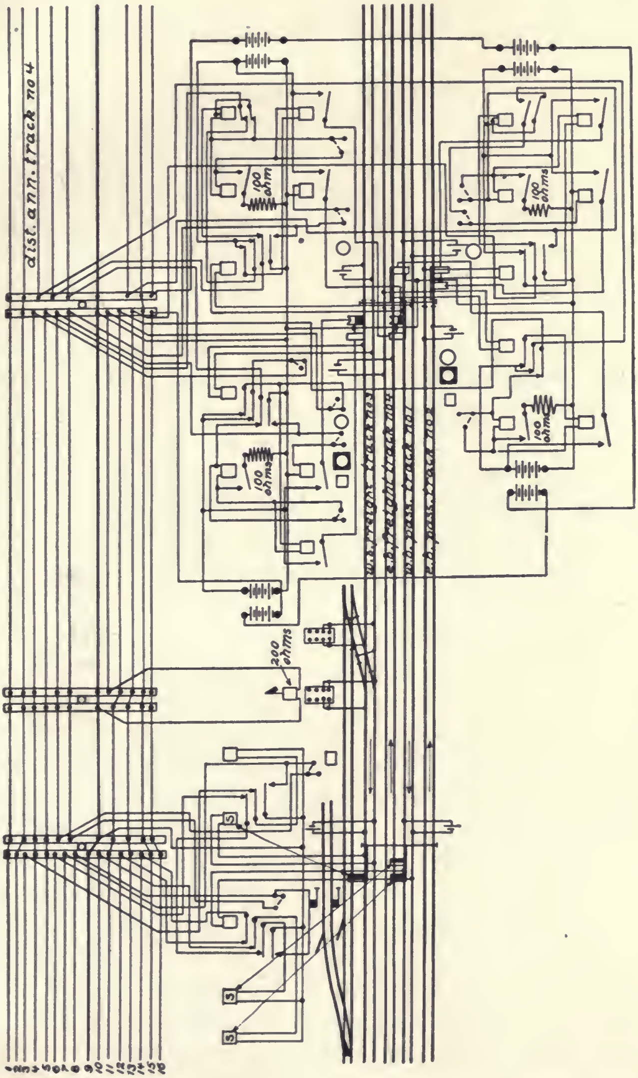


Fig. 207

daylight by the engineman; but in the dark this is difficult, as he is only governed by the color of the intercepted light. Hence, a partly cleared or improperly displayed member, while

readily perceived in the daytime, at night may give a clear indication when such is wrong. Sight shields only remedy this difficulty, by showing the engineman that he must come to a stop, by reason of the rules governing improperly displayed signals.

Fig. 204 shows a generator and switchboard used in a typical transmission scheme for storage battery charging. The generator has a terminal e.m.f. of 500 volts, and in this case is bipolar and compounded. The series winding is shunted for adjustment of the compounding, an equalizer being used when two or more are connected in multiple. The switchboard contains, on each side, a main switch, *D*, circuit-breaker *E*, fuses *F*, ammeter *A M*, and a voltmeter, *V M*, which is thrown on either side of the lines by switch *S*. The circuit-breaker will open on "no voltage" or "reverse current," by the action of the shunt coil, *A*, or through an overload by the series coil, *B*, the contact blades being shown at *C*. *G* is a rheostat for changing the terminal voltage by variation in the current passing through the shunt field-coils. The individual storage batteries, both east and west, are connected in series. The use of two multiple lines assures the maximum distance of transmission at a minimum line loss.

We have, in Fig. 205, a comprehensive, normal, clear circuit, such as occurs on the L. S. and M. S. R. R., which includes most of the connections that have heretofore been considered. In view of the preceding descriptions, this need not be analyzed, but it covers the standard storage battery-line wire arrangement now being extensively applied to trunk lines.

In conclusion, Figs. 206 and 207 contemplate normal danger circuits on the Erie Railroad, from Bergen, N. J., to Suffern, N. Y. Included therein are slot control of mechanical semaphores, a charging line arrangement, and indicators at *B J*, tower. This exemplifies the circuits usually employed at interlocking plants, and is typical of the electrical control of long-established mechanically operated semaphores, and their application as a supplement to an automatic network.

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